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CIVILIZATION AND SCIENCE.[1]

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PART II.

VI.—The Technico-Inductive Period.

BUT there was still a long road to travel, before even the threshold of the temple of truth was reached. Nothing is better fitted to humble the spirit of speculation, which is ever and again lifting its head in Germany, than a contemplation of the first faltering steps of natural science, after it had at last been aroused from its slumber. If speculation were of any avail, one might suppose that it would succeed, above all, in throwing light upon a subject so comparatively accessible to our understanding as the laws of motion. But as Kant in later times failed to discover *a priori* the conservation of energy, so did the foremost minds of the Renaissance fail to find *a priori* the simplest truths of mechanics—truths since so transformed, if the expression be allowed, into flesh and blood of civilized man, that nativists[2] might be tempted to regard them as innate. To us it appears inconceivable that once it required the profoundest meditation to discover the first law of motion, the inertia, as it is called, of matter, in virtue of which the motion of a body does not change without an external cause; that, down to the period of which we are speaking, no one had acquired a clear notion as to why a rolling ball at last stands still. Galilei even at first believed that a body, water, for instance, may move in a circle, without being

[1] An address delivered before the Scientific Lectures Association of Cologne. Translated from the German by J. Fitzgerald, A. M., and carefully revised by the author.

[2] Upholders of the doctrine of *innate ideas*.

held in that course by an external cause.'[1] Kepler least of all had any clear conception of the laws of motion, but held views closely resembling those of Pythagoras. But when we consider that, not reckoning Archimedes, whose teaching was not understood or quickly forgotten, the human mind had for two thousand years not made a step of progress in this matter, we cannot but wonder at the rapidity with which such ideas are now developing; and herein we recognize the influence of that new sense which has been awakened among civilized nations by monotheism. Scarcely had the human mind abandoned the waving sea of speculation, escaped from the *mare tenebrosum* of scholastic theology, and set its foot on the firm land of inductive investigation, when it triumphantly sped along a track which brought it at one bound, as we might say, up to the highest accessible point; for only fifty years separate Galilei's "Discorsi" from Newton's "Principia," and the formulation by Leibnitz, in the same year 1686, of the doctrine of the conservation of energy.

And so at last with a rapid succession of geographical, astronomical, physical, and chemical discoveries, came the period whose benefits we enjoy, and to which we give the name of the *technico-inductive period*, because its results are due to the fact that in natural science speculation has given way to induction, the *μεθόδος ἐπακτική*, of which it is so hard to give an idea to an outsider, because strictly it is nothing else but common-sense applied to a given problem.

The study of this new phase of human history is as full of comfort and encouragement as the study of the mind's enslavement, by the phantasms of its own imagination during the "middle ages," was painful and depressing. Nay, who will deny that, in reviewing the whole history of mankind, with the exception of the golden age of Grecian civilization, which passed away as rapidly as everything beautiful does, no nobler spectacle is to be seen than that which is beginning to unfold itself to our view, and which is even now becoming grander from day to day.

Here we have a universal history very different from the histories which commonly go by that name, and which tell of nothing save the rise and fall of dynasties and empires, treaties and disputed successions, wars and conquests, battles and sieges, rebellions and party strifes, devastation of cities and harassment of populations, murders and executions, court conspiracies and priestly intrigues; which exhibit to us, in the war of all against all, nothing but ambition, avarice, and sensuality, violence, treachery, and revenge, fraud, superstition, and hypocrisy. Only at rare intervals is this dark picture relieved by the cheering apparition of genuine princely magnanimity, or of peace and prosperity among the people, oftener by the soul-stirring deeds of a heroism which, alas! too often is spent in vain. For, whither ultimately leads this

[1] Concerning this stage of the mind's development, consult Whewell, "History of the Inductive Sciences," vol. ii., p. 23, *et seq.*

road, whose track lies across rivulets of tears and through a sea of blood? Can we discern in political history any steady progress effected by the play of the forces which constitute its subject-matter? Do kings grow wiser, or peoples more sober-minded? On the contrary, does not the lesson taught by history seem to be this, that history teaches no lesson? Till modern times, did humanity steadily and consecutively advance from step to step in liberty, morality, power, art, well-being, and science? Does not the history of which we speak present to our view rather a labor of Sisyphus, and does not the very conception of different periods of civilization imply the downfall of those civilizations?

Alas! we know only too well that this kind of history was for a long time the only one known to man; and for the mass of people it will continue to be the only one. The mighty game of chance, played for stakes the value of which is known of all men, and the strife of passions it calls forth—this drama, whereof man himself is at once the poet and the performer, irresistibly attracts the ingenuous mind, and is full of the profoundest lessons, however little they may be regarded.

But contemplate for a moment infinite space strewed with nebulæ in the chaotic state, with star-clusters and solar systems. Imagine, as an invisible point in this infinity, our own sun as it speeds on into unknown regions of the heavens, surrounded by its planets, each one revolving in its own proper orbit—Jupiter, the giant-planet, with his moons, and Saturn with his rings. Again, imagine our earth, a point in this system, shooting through universal space at the rate of a falling star, and rotating on its axis from morning to night, from night to morning—"mountain and sea borne along in the ever-rapid course of the spheres." Descend, in imagination, into its fiery interior, and learn the great outlines of its history. After ages innumerable, the flood of molten lava at its surface became sufficiently cooled to admit of the existence of life; organisms succeeded one another till, at length, the history of our own race begins in the twilight of fable, now, however, illumined by the discoveries of prehistoric research.

We will call this mode of looking at terrestrial phenomena, opposed as it is to the anthropocentric point of view, the *Archimedean perspective*, because thereby we in thought take a standpoint beyond the earth, just as Archimedes desired to have a *locus standi* outside the earth, in order to move it.

How lowly and insignificant do earthly things appear when thus contemplated! How petty now seem all those occurrences which we are wont to regard as so weighty, that we comprehend them under the high-sounding name of "universal history," whereas, in truth, one half of them belong to the history of the wars, and the other half to the history of the hallucinations of only a few civilized nations! How vain and foolish are wars for a patch of land or for blood-stained laurels! In presence of the sublime spectacle of the universe, may we not exhort to reconciliation and harmony the race of man, ever wrangling about piti-

able trifles? How odd, from the Archimedean perspective, appear the fevered imaginings of mankind about higher beings inhabiting somewhere above our heads the icy, ether-filled cosmical space, vibrating with force-radiations, and pervaded by meteor-streams! How utterly absurd is the idea of an assembly of the gravest, most learned, and most profound men of their times sitting to decide whether Father and Son are of the same or of like substance! How ridiculous, were it not so tragical, was the scene of Galilei's abjuration, when we think of him and his judges being carried along together "in the ever-rapid course of the spheres!" But oh, how doubly hideous appear the massacre of St. Bartholomew and those *autos da fé*, whose atrocities reach their culmination in the burnings of Giordano and Servetus! For the objects of veneration to whom these hetacombs were immolated there is no place in infinite space from the Archimedean standpoint, and they will have to be collocated in the fourth dimension.

In truth, in this so-called "universal history," there is but one light to guide us, which, however, has not often been employed hitherto: that is the doctrine of epidemic mental disease. As in mental diseases occurring in individuals, so here, it is hard to draw the lines of distinction between insanity and depravity. But the few who contemplate, as it were, from the lofty summit of an intellectual crag, in an Archimedean way, the doings of mankind here below, cannot be very far wrong in holding *that* to be the true history of the human race which, through all its ups and downs of fortune, its crimes and its errors, traces for us its gradual rise out of a state of semi-brutishness, its progress in arts and sciences, its growing dominion over Nature, its daily increasing well-being, its liberation from the bonds of superstition, and its steady approximation to those ends which make man what he is. In polity and war, whose unprofitable and monotonous oscillations are the subject-matter of political history, man had predecessors among invertebrate animals even; but the human race alone offers a history of civilization. Hegel calls the horse and iron the "absolute organs for establishing civilized power." With greater justice we say that natural science is the absolute organ of civilization, and hence that *the history of natural science is the proper history of the human race.*

The punier man seems to be, as viewed from the Archimedean standpoint, the grander appear his achievements in the face of Nature, the nobler his efforts to subdue her, the more attractive the history of his intellectual conquests. As this history has memorable days and places different from those of political history, so, too, of course its kings and heroes differ from the kings and heroes to whom the thoughtless world is wont to pay homage. Who is it that in this history rivets our attention at the beginning of the eighteenth century? Not that king, surrounded by his confessors, his mistresses, and his incendiary marshals, against whom, as Ranke said to Thiers, we still bore arms after Sedan; but that greatest of men, Sir Isaac Newton, deeply pondering on a prob-

lem beneath the elms of Cambridge. Who at the beginning of this century? Not, amid the ruins of Moscow, the indomitable man who invented chauvinism as the instrument of his ungovernable selfishness, but Alessandro Volta, contriving, at his villa on Lake Como, the artificial electrical organ which gave to man the power of omnipresence, as it were; or that other conqueror of space, George Stephenson, setting in motion, in his coal-blackened cottage at Killingworth, the model of his railway-locomotive.

It were a noble task to describe the revolution that natural science has quietly produced in the condition of the human race during the last two or three centuries. Just as it has lifted from over our heads the confining roof of a solid firmament, so, too, has it liberated us intellectually. For every one who hearkens to her teaching she has fulfilled the aspirations of the poet, who, amid the throng of courtiers in the antechamber of Octavian and all the splendor of historical greatness, wistfully bethought him of the disciple of Epicurus as he reposes in powerful calm:

> "Felix qui potuit rerum cognoscere causas,
> Atque metus omnes et inexorabile fatum
> Subjecit pedibus, strepitumque Acherontis avari." [1]
>
> "How blest the sage whose soul can pierce each cause
> Of changeful Nature and her wondrous laws;
> Who tramples fear beneath his foot, and braves
> Fate and stern Death, and hell's resounding waves!"
>
> *Sotheby's translation.*

In the place of miracle, natural science has substituted law. Ghosts and spectres have disappeared before it as before the first rays of light in the east. It has broken the power of ancient lies; it has put out the fires in which witches and heretics used to be burned; it has placed a keen-edged weapon in the hands of historical criticism. But it has also curbed the pride of speculation. It has discovered the limits of knowledge, and taught its disciples to look down without dizziness from the airy heights of sovereign skepticism. How easy and free one breathes on those heights! How nearly inaudible to the mind's ear the hum of the vulgar multitude in the torrid lowland, the complainings of disappointed ambition, the battle-cries of nations! As of the anthropocentric, so, too, of the Europocentric idea natural science has made an end. As it opened the Ghetto, so it burst the fetters of the negro. How different its conquest of the world from that of Alexander or the Romans! If literature is the true intranational bond of nations, their international bond is natural science. Voltaire could abhor Shakespeare, but Newton he revered. The triumph of the scientific view of Nature will to future ages appear as a step in human development comparable to the triumph of monotheism 1,800 years ago. It matters not that the

[1] Virgil, "Georgics" ii., v., 490, *et seq.*

people will never be ripe for this form of religion, for where have they ever realized the ideal of Christianity?

If we ask ourselves where in literature did this conception of the universe first make its appearance, the answer will be, "In Voltaire." That mental characteristic of Voltaire, to which David Friedrich Strauss has not done full justice, namely, the scientific habit of thought which he contracted in England and developed at Cirey, enabled him clearly to perceive the difference between political history—the only form of history known down to his time—and the history of civilization; and in the latter with a boldness and perspicacity all his own to show retrospectively and prospectively the part played by natural science. In a hundred of his essays, letters, and philosophical novels, this fundamental idea rises to the surface; but, with the amazing versatility of his genius, he to-day, as in the "History of Charles XII.," looks upon events from the anthropocentric standpoint; to-morrow, as in the "Micromegas," from the Archimedean perspective.

Following in Voltaire's footsteps, the encyclopedists further developed this conception. They still more positively than he called attention to the methodical utilization of the forces of Nature as perceived in their regular working. Hence Diderot's partiality for the mechanic and useful arts, a trait well noticed by Rosenkranz, in which Diderot agreed with a man who also in a moral sense had come to meet him from the other shore of an ocean—with Benjamin Franklin, the father of utilitarianism.

What they dreamed is now more than accomplished. Man, whom we first met as a tool-making animal, is now become a rational animal who travels by steam, writes with lightning, and paints with the sunbeam. The reconversion into work of the sunlight stored up in "black diamonds" multiplies his energy a million-fold. The Seven Wonders of antiquity, the engineering works of the Romans, bear no comparison with the enterprises every day undertaken by our own generation. The periphery of our planet threatens to become too narrow for man's genius. Hardly any secrets do its heights and its depths still conceal from him. Whithersoever man is powerless to go bodily, his mind penetrates with the aid of the magic key of calculation. In the blackest night, on the stormiest sea, his bark steers the shortest course; she dexterously shuns the track of the destroying typhoon. Geology does all that the divining-rod was once supposed to do, giving us plentiful supply of water, salt, coal, and petroleum. The list of the metals is ever growing, and yet chemistry has not discovered the philosopher's stone; some day that too will be found, perhaps. In the mean time, it vies with organic Nature in producing things both useful and agreeable. From the black, noisome waste-products of coal-gas, which has transformed every city into another Baku, chemistry derives coloring-matters before which the splendor of tropic plumage pales. It prepares perfumes without sun and without flower-beds. And though it might not have solved Samson's riddle,

who could have solved its own riddle of how to get sweetness out of what is disgusting? Gay-Lussac's art of preserving articles of food has done away with the distinction of seasons for the poor as well as for the rich. The poisoner, with impotent rage, sees all his crafty schemes unveiled. The destroying angels of small-pox, plague, and scurvy, are chained. Lister's bandage excludes from the wounds received on the battle-field the insidious and poisonous germs revealed by the sunbeam. Chloral spreads the wings of the god of sleep over the most tortured soul; and Chloroform sets at naught, at our pleasure, the Biblical curse of woman.

Thus is fulfilled the saying of that prophet of science, Francis Bacon, that knowledge is power. All European nations, the Old World and the New, are running a race on this course. A distinguished critic of art not long ago laid down the proposition that in the development of the plastic arts is to be found the measure of the height attained by humanity at any given time. If that is so, then the time from Phidias down to Lysippus, and the *cinque-cento*, would have seen the highest development of humanity ever reached hitherto, and perhaps never to be attained again; the present century would at best give out but a feeble flicker of culture, as having produced the cartoons of Cornelius! This measuring the height of man's development by one single aspect of human activity is in itself a false idea, and hence the judgment expressed above is as erroneous as is, for instance, the one-sided ethical conception of man held by Semitism. But if there exists any criterion which, *per se*, gives a measure of man's progress, it would appear rather to be the degree of mastery over Nature that has been attained in any age. The history of art is influenced by accidental circumstances, as talent, taste, patronage, prosperity. In the investigation and subjugation of Nature alone there is no standing still; the store is ever increasing, and the creative force is ever producing more and more. Here alone does each successive generation stand securely on the shoulders of their predecessors. Here alone is the disciple disheartened by no *nec plus ultra*, oppressed by no weight of authority, and even mediocrity finds an honorable place, if it does but seek the truth diligently and conscientiously. Finally, it is not art that saves civilization from another downfall. Art, with all its glory, would to-day, as often before, under the same circumstances, fall a helpless prey to barbarism, were it not that natural science gives to our present life a security, which we are so accustomed to consider as the natural condition of the existence of modern civilization that we do not even think of asking whence that security is derived.

We are all familiar with Macaulay's prophecy of the tourist from New Zealand who, while the Roman Church still exists in undiminished vigor, shall, in the midst of a vast solitude, take his stand on a broken arch of London Bridge to sketch the ruins of St. Paul's. In this gloomy picture Macaulay indulges pessimistic views such as are very likely to

be entertained by the historical investigator who has constantly before his eyes the vicissitudes of political affairs. But in his ἔσσεται ἦμαρ the great rhetorician falls into the same error as he falls into immediately afterward in holding that the foundation of natural theology is to-day just what it was in earlier times; that, in philosophizing about the origin of things, a thinker at the present day is not more favorably situated than Thales and Simonides; and that, as concerns the question, what becomes of man after death, a highly-educated European, left to his unassisted reason—in other words, unaided by revelation—is as little likely to be in the right as is a Blackfoot Indian. In both cases Macaulay overlooks a fact alien to him as a writer of political history, and, as it would appear, particularly so to his special genius—namely, the changes wrought, and daily being brought about with ever-increasing rapidity, in the condition of the human race by natural science. Modern humanity is different from mediæval and ancient humanity; the condition, the views, and the ideas of our race, in ancient and in modern times are no longer comparable *inter se*, thanks to the new elements introduced by natural science. Our science and civilization securely rest on the basis of induction and the useful arts; ancient science and civilization were built upon the shaky foundation of speculation and æsthetics.

VII.—The Dangers which threaten Modern Civilization.

What now can check modern civilization? What lightnings can ever shatter this tower of Babel? It makes one dizzy to think of what mankind is destined to be a hundred, a thousand, ten thousand, a hundred thousand or more years hence. What is there to which it may not attain? As it nowadays, mole-like, works its way through mountain-chains and under the ocean, why may it not at some future time imitate the flight of the bird? And, as it has solved the enigmas of mechanics, why should it not solve also the enigmas of mind?

Alas! it is decreed that trees shall not reach the sky. It is more than doubtful that man will ever fly; but the time never will come when he can tell how matter thinks. It is easier for us to reconcile ourselves to these limitations than to that everlasting age of ice which science remorselessly points out to us as the last scene in the drama of human affairs. Thus curiously enough it happens that, whereas natural science had seemed to promise to civilization a perpetual duration by insuring it against the inroads of barbarism, it again makes the assurance void and robs us of our hopes of a stable habitation on the earth. The day will come when man no longer can say, "Lo! Homer's sun sends down his beams even on us;"[1] a day when the earth, over and over ice-clad, will travel sluggishly around the sun, whose fires will then burn only with a ruddy glow; a day when, just as in the begin-

[1] "Und die Sonne Homer's, siehe, sie lächelt auch uns"—concluding pentameter of Schiller's "Spaziergang."

ning, "Light was," because then the first eye opened, so "Darkness will be," because then the last eye closes.

But from this fate millions of years still separate our race. A young man does not allow himself to be thwarted either in his pleasures or in his ambitions by thoughts of the infirmities of age which await also him, or of the inevitableness of death. So, too, we are but little concerned about the fate that threatens our unimaginably remote posterity. Should we feel greater alarm for the immeasurably nearer danger which threatens our present civilization in the exhaustion of our coal-fields within a calculable period of time? No one, who knows how difficult it is to substitute another source of power, can contemplate without solicitude our scandalous waste of coal. The present demands of manufacturing industry are not very easily checked, it is true; besides, "the living are always in the right,"[1] and later generations must find out for themselves a means of navigating the ocean without coal; nevertheless, the British Parliament would be better employed in devising measures to prevent the waste of coal (which is greater in England than elsewhere), than in busying itself with questions of experimental physiology, as it has lately been doing to the injury of science and the impairment of its own dignity.[2]

Civilization is also threatened in another quarter. In the face of a new barbaric invasion, it need have no fear; but in the heart of every great city, in the busy hives of industry, civilization has itself brought forth a race which, misguided by insane or reprobate leaders, may be to it a source of greater danger, by their ignorance and brutality, than were the Huns and Vandals to the civilization of the ancient world. So wrote Macaulay, and Macaulay did not live to see the year 1871. Again, he takes too dark a view. In point of fact, these dangers are confined to certain points in time and space. Culture in general has nothing to fear even from the Red Internationale. The Servile War, the War of the Peasants, and the Revolt of the Anabaptists, were class-psychoses of the same character as the present disturbances. As we regard the former, so will future generations regard the insurrection of June and the Commune; and they will themselves have to deal with the same disease under other forms.

The peril of which I would here speak is not one which directly threatens the stability of civilization. We are concerned rather about the questionable form which civilization tends to assume, judging from the direction in which it is at present developing. It is not easy to define this peril, inasmuch as it is the product of a multitude of trivial circumstances, amid which we ourselves live, and whose influence steals

[1] "Der Lebende hat Recht."—SCHILLER.

[2] *See* Ludimar Hermann, "Die Vivisectionsfrage," Leipzig, 1877. Translated into English by Archibald Dickson, under the title of "The Vivisection Question popularly discussed," London, 1877. E. Du Bois-Reymond, "Der physiologische Unterricht sonst und jetzt," Berlin, 1878, § 21–23.

over us so insensibly that some degree of abstraction and keen observation is needed in order to detect it. This danger has already often been pointed out with apprehension; in fact, it is a very common thing to speak of the state of affairs from which it results as being one of the evils of our time; but yet it is not always clearly perceived that we have here to do with a necessary consequence of the progress of civilization as set forth in the preceding considerations.

When cultivated one-sidedly, natural science, like every other form of activity under the same conditions, narrows the mental horizon. Under such circumstances natural science confines our vision to what lies nearest to us, what is palpable, what can be directly apprehended with apparent certitude by the senses. It turns the mind away from more general and less positive considerations, and disaccustoms it to act in the region of the quantitatively indeterminable. In a certain sense we hold this to be a priceless advantage for natural science; but, where this tendency dominates exclusively, it is not to be denied that the mind becomes poorer in ideas, the fancy in images, the heart in sentiment, and the result is a narrowness, a dryness, and a hardness of mental constitution, abandoned by the Muses and Graces. Again, it is a peculiarity of natural science that on the one hand it has a part in the highest aspirations of the human soul, while on the other by insensible gradations it passes into handicraft, into activities whose sole end is lucre. Under the ever-rising demands of every-day life, a steady deviation in the latter direction is inevitable. That side of scientific activity which has to do with the useful arts is ever, unnoticed, coming more and more into the foreground; generation after generation find themselves more and more bent on caring for material interests. Even the universal participation in the over-estimated benefits of political life diminishes the respect for ideas. Amid the unrest which has taken possession of the civilized world, men's minds live as it were from hand to mouth. Who now has the time or the inclination to go down into the deep well of truth, to plunge into the sea of the Ever Fair? Education nowadays, too often an unorganized patchwork, consists of individual facts plucked up by the roots, so to speak, useful it is true, but dry and crude. Few now are concerned about the mode in which the truth has been discovered, or about the relations between things perceivable only in reascending to their origin—to say nothing of the charm of perfect form. Art and literature prostitute themselves to the gross and variable taste of the multitude, swayed hither and thither by the daily newspaper. Where fame lasts only for a day, one of the noblest incitements of human nature—the thought of being famous after death—ceases to have any effect. Hence the decay of intellectual production, which brings forth imperishable masterpieces only when the mind gives itself to its work with whole-hearted devotion and with patient fidelity. And if, as Fontenelle has said, industry is indebted for its quickening impulse mostly to pure

science, even industry is compromised by what is in part its own work. In short, Idealism is succumbing in the struggle with Realism, and the kingdom of material interests is coming.

It is no surprise that this aspect of modern civilization should be most noticeable in a country where the creation of material resources and the removal of natural obstacles were for a long time of prime necessity; where an immigrant population had, in a measure, to begin a new life, and most of them had as it were burned their ships behind them; where no historic memories and literary traditions were available for stopping the tendency of the popular life, too exclusively directed toward the useful arts and the acquisition of wealth. It is no wonder that America has become the principal home of utilitarianism. While at times the very first conditions of human society are there in dispute, it is in America especially that those existences come into being whose wealth, luxury, and external polish, contrasting as they do with their ignorance, narrowness, and innate coarseness, give one the idea of a neo-barbarism. In view of this aspect of American life, which has been again and again portrayed by writers, from Sealsfield down to Bret Harte, it has come to be the custom to characterize as an *Americanization* the dreaded overgrowth and permeation by realism of European civilization, and the rapidly-growing preponderance of manufacturing industry. Later the starry flag has waved in a war for an idea, a glory which the tricolor has been wont to claim for its own—and then has, like your true mercenary, demanded its pay for service done. Still another starry flag may the land of the future confidently oppose to such reproaches as are implied in the term "Americanization"—the flag of its young literary honors, each star being some name illustrious in science, in song, or in story. However, the term "Americanization" is now naturalized, nor will non-Americanized Americans object to the employment of it, as most of them are quite ready to admit the weak point in the young giant's education which this term is used to designate.

But, in thus animadverting on American civilization, is it not a fact that we see the mote in our brother's eye, but perceive not the beam that is in our own eye? What of the resistance that ought to be made to these redoubtable tendencies by our German civilization, ancient and firmly rooted as it is, when compared with the American? Unless we give way to one of our latest-cherished self-delusions, we must confess that we have already made such progress in "Americanization" as should give us pause. Germany is become united and powerful, and the longing of our youth to see the German name again respected by land and sea has been fulfilled. Who would find fault with such an achievement? But go back in thought to the divided, powerless, provincial Germany of our youthful days—passing as it were from the cold splendor of the imperial city into the narrow streets of some old town in Middle Germany, with their overhanging gables, and the house-fronts hung with grape-vine and ivy—is there not something lacking

in the noisy Present, with all its glittering and dazing magnificence? Must we not, in the words of the "Schwalbenlied," exclaim, "Oh, how remote from me is that which once was mine!" In the revolution which Germany has undergone within a generation, has not the good been sacrificed as well as the evil? Besides its vague longings, its futile struggling, its uneasy doubts as to its own powers, has not the German nation furthermore dropped somewhat of its enthusiasm for ideals—its unselfish striving after truth, its deep and quiet inner life? Like a dream the short-lived bloom of our literature has vanished. As politics and natural science, with their harsh realities, have silenced the delightful *causerie* of the Parisian *salons*, so here, too, have they given poor entertainment to the descendants of the heroes of classic story and of romance. Goethe himself, were he now a young man, would, in all probability, leave "Götz," and "Werther," and "Faust," unwritten, and would rather practise in the Imperial Diet his power of public oratory, diagnosed in him by Gall, but which, during his life, he tested only with the "birds of Malcesine."[1] With all the splendor of German science to-day, we painfully miss, in the rising generation, the noble passion which alone guarantees the continuity of intellectual effort. The recently reawakened liking of the Germans for philosophic speculation simply proves the truth of the old saying—

"Naturam expellas furca, tamen usque recurret;"

but it is not calculated to quiet our apprehensions, with regard to the universally-diffused and rapidly-increasing indifference of our youth toward everything that they cannot see through and through, or that does not bring money or advancement.

[*To be continued.*]

PROFESSOR HUXLEY'S ADDRESS AT THE HARVEY TRICENTENARY.

MR. PRESIDENT: In attempting to fulfill the task you have imposed upon me, I am mindful that I address myself to an audience which is already familiar with William Harvey's claims to the honor which we are assembled to show him. For, within these walls, the memory of your illustrious Fellow and chief benefactor is kept perennially green by the customary piety of the speaker of the annual oration which Harvey founded; and his merits have been placed before you, with exhaustive completeness, by a long succession of able and eloquent orators. Even if the time and place were fitted for a disquisition on these topics, I could not hope to be able to add to the facts

[1] Birds in Aristophanes's sense. The allusion is not easy to explain in a few words.—(*See* Goethe's "Italian Journey.")

already known, or to place them before you in a new light. And, happily, this is not my function; I have to act simply as your remembrancer, to play the part of the herald who announces the familiar titles of a monarch on a state occasion.

Harvey's titles are three: he was the discoverer of the circulation of the blood; he wrote the "Exercitatio de Motu Cordis et Sanguinis;" he formulated anew the theory of epigenesis, and thereby founded the modern doctrine of development.

His first and, in general estimation, his greatest title to our honor has been challenged; but only to the confusion of the challengers. A century ago, your Fellow, Dr. Lawrence, in the excellent memoir prefaced to the college edition of Harvey's works, met the arguments of those who had, up to that time, attempted to dim his fame, with a solid refutation, which has never been answered, and to my mind remains unanswerable. In our own day, Dr. Willis has stated the facts of the case, and deduced the inevitable conclusion, with no less force and cogency. And, having taken some pains to get at the truth of the matter myself, I may state my clear conviction that Harvey stands almost alone among great scientific discoverers; not so much that, as Hobbes said, he lived to see the doctrine he propounded received into the body of universally-accepted truth, but because that doctrine was both absolutely original and absolutely new. I have yet to meet with a single particle of evidence to show that, before Harvey declared the fact that the blood is in constant circular motion, there was so much as a suspicion on the part of any of his predecessors or contemporaries that such is the case. Neither in Galen, nor in Servetus, nor in Realdus Columbus, nor in Cæsalpinus, is there a hint that a given portion of blood sent out from the left ventricle passes through the body and the lungs and returns to the place whence it started; yet this is the essence of Harvey's discovery.

Hence, when we hear of pompous inscriptions being put up in Spain to Michael Servetus, "the discoverer of the circulation," or in Italy to Cæsalpinus, "the discoverer of the circulation," it is well to recollect that churchyards have no monopoly of unhistorical inscriptions. Indeed, have we not ourselves, within easy walking-distance, that famous monument, the subject of Pope's scathing but just lines:

> "And London's column, soaring to the skies
> Like a tall bully, lifts its head and lies?"

Sir, I have no sympathy with *chauvinism* of any kind, but, surely, of all kinds that is the worst which obtrudes pitiful national jealousies and rivalries into the realm of science. We will not shame ourselves by permitting the fact of Harvey's English birth to enter into the consideration of his claims as a discoverer; but those claims once established beyond dispute, it is, I hope, something nobler and better than mere national vanity which brings us together to celebrate his birth;

to take an honest pride that such a man came of our English race; and as, I hope, to feel the deep responsibility which is laid upon us to have a care that the stock which in the same hundred years bourgeoned out in a Harvey and a Newton, shall not have its capacity for producing like growths, in the present and in the future, starved by devotion to mere material interests, or stunted by ignorant outcries against scientific investigation.

The second title which I have claimed for Harvey is that of author of the "Exercitatio de Motu Cordis et Sanguinis." And that title is, happily, quite indisputable. But some may suppose that I have so far thrown myself into the spirit of my assumed office as to insert a superfluous appellation—a sort of "Defender of the Faith." However, this would be an error. Harvey might have discovered the circular course of the blood; he might have given sufficient evidence of his discovery; and yet he might have been quite incapable of writing that little essay of fifty pages which no physiologist of the present day can read without wonder and delight. For, not only is it a typical example of sound scientific method and of concise and clear statement; but, in addition to the evidence of the course of the blood through the body, it contains the first accurate analysis of the motions of the heart; the first clear conception of the mechanism of that organ as a pumping apparatus; the first application of quantitative considerations to a physiological problem; and the first deductive explanation of the phenomena of the pulse and of the uses of the valves of the veins. "Libellus aureus," Haller called it—and never was epithet more aptly bestowed.

Harvey's third title to honor is the authorship of the "Exercitationes de Generatione." In this treatise Harvey grapples with two of the most difficult problems of biology—the physiological problem of generation and the morphological problem of development. It was simply impossible that he should solve these problems, for they can be approached only through the microscope; and Harvey was dead before Hooke, Malpighi, Swammerdam, or Leeuwenhoek, the fathers of microscopy, began their work. He saw the circulation in shrimps "ope perspicillo" indeed—but the perspicillum was a mere hand-glass. Hence it is not wonderful that Harvey's theory of fecundation is altogether erroneous; and that he is no less mistaken respecting the nature of the parts of the embryo which first make their appearance and the mode of their formation.

Nevertheless, just as it is the fate of dullness to be blind to the significance of justly-observed facts, so is it the rare privilege of men of the highest genius to discern the true light among the *ignes fatui* of error. They know the truth, as Falstaff discerned the true prince among his pot companions, by instinct. Explain the matter how we will, it is an indubitable fact that, though Harvey's fundamental observations were either inadequate or erroneous, some of his most important general conclusions express the outcome of modern research.

For a whole century Harvey's successors, even though the illustrious Haller was among them, went wrong when Harvey was right; and though Caspar Wolff returned to Harvey's views and thereby laid the foundation of modern embryology, the definitive triumph of the doctrine of epigenesis is the result of labors which have been effected within the memory of living men.

Such appear to me to be the chief claims of Harvey to be held in everlasting honor among men of science. We know that they represent a mere fraction of what he did. But the violence of an unhappy time has robbed us of the rest. I should trespass unwarrantably on your time if I insisted on the applications of Harvey's discoveries to medicine and surgery in the presence of those whose daily avocations bear witness to them.

I have hitherto dwelt upon the claims to our honor of Harvey the philosopher; one word, in conclusion, concerning Harvey the man. There have been great men whose personality one would gladly forget: brilliant capacities besmirched with the stains of inordinate ambition, or vanity, or avarice; or soiled by worse vices; or men of one idea, unable to look beyond the circle of their own pursuits. But no such flaw as any of these defaces the fair fame of William Harvey. The most that tradition has to say against him is, that he was quick of temper and could say a sharp thing on occasion. I do not feel disposed to cast a stone against him on that ground; but rather, such being the case, to marvel at the astonishing, not only self-control, but sweetness, displayed in his two short controversial writings—the letters to Riolan; a man who really was nothing better than a tympanitic Philistine, and who would have been all the better for a few sharp incisions.

Moreover, in such a temperament, while the love of appreciation is keen, the sense of wrong at unjust and willful opposition is no less strong. But I do not recollect, in all Harvey's writings, an allusion to the magnitude of his own achievements, or an angry word against his assailants.

Ready to welcome honor if it came, but quite able to be content without it; caring little for anything but liberty to follow in peace his search into the ways of the unfathomable cause of things—"sive Deus, sive Natura Naturans, sive Anima Mundi appelletur"[1]—one fancies this man of the true Stoic stamp would have summed up his eighty years of good and evil in the line of the poet, which was the favorite aphorism of his great contemporary, Descartes:

"Bene qui latuit bene vixit."

But he lived too well that the memory of his life should be allowed to fall into oblivion; and we may hope that recurring centennial anniversaries will find our successors still mindful of the root whence their ever-widening knowledge has sprung.—*Nature.*

[1] "Exercitationes de Generatione," Ex. 50.

THE TEREDO AND ITS DEPREDATIONS.[1]

By Dr. E. H. VON BAUMHAUER,
COMMISSIONER TO THE CENTENNIAL EXHIBITION FROM HOLLAND.

I.

DURING a period of about twenty-five years previous to 1858, the injuries caused to the timber of marine constructions by the *Teredo navalis* were rarely noticed in Holland, when, during the summer of that year, public anxiety was awakened afresh on that subject. Some repairs, undertaken at that time, of the marine works of the port of Nieuwendam, a village situated on the Y, brought to light the fact that all the piles broke off at the slightest blow, and were found to be entirely eaten off by the teredo.

The late secretary of the Royal Academy of Sciences of Amsterdam, Prof. W. Vrolik, called the attention of the Academy to this subject at a meeting held November 27, 1858, and the Academy appointed a commission from its own members, composed of Messrs. W. Vrolik, P. Harting, D. J. Storm Buysing, J. W. L. van Oordt, and E. H. von Baumhauer, charged with the duty of collecting and examining into all facts known concerning the natural history of the teredo, and, at the same time, to inquire into the best means for preserving wood from destruction by that mollusk.

Considering the great importance of this question to our country, bathed on all sides by the sea, the commission asked the assistance of the Government in its work, which was readily granted. This subject being of equal importance to other countries situated on the sea, and researches into the means of preventing the ravages of the teredo having been undertaken and the results published, especially in England, France, and Belgium, I have thought that a brief communication of the results we reached would be interesting and perhaps useful abroad, especially as our work was conducted on a large scale.

Before relating the experiments conducted by the commission, I propose to give a sketch of the examinations made by Mr. Harting, on the structure of the teredo and its mode of life, which have been very carefully studied by M. P. Kater, at Nieuwendam.

On the Mechanism of the Apparatus with which the Teredo perforates its Galleries.—The researches of several leading naturalists into the habits and structure of mollusks which perforate hard substances, such as wood and stone, have shown that some of them, which are found in calcareous rocks, make their excavations through some chemical means, i. e., by the dissolving action of an acid secretion, while the teredos and some others employ in their work purely mechani-

[1] Extract from the Archives of Holland, vol. i., translated by Edward R. Andrews.

cal means only. The manner in which the teredos proceed in their work has not, however, been clearly pointed out. In fact, while Hancock does not consider the shell, but the fleshy foot, as the boring instrument, and Quatrefages attributes that *rôle* to a part of the mantle of the animal, extending like a fold to the margin of the shell, Corilland has indicated the shell itself as the perforating instrument. By fastening the shell of a teredo on the end of a small stick of wood with gum, and turning it between the thumb and finger, he has succeeded, after four and a half hours' labor, in boring a hole in wood thirty millimetres deep. Mr. Harting arrived at the same conclusions by a careful microscopic examination of the shell and the muscular system of the teredo. We will point out the principal results of his studies, with illustrations to make them clear:

The shell is composed of two valves of equal size, which are not fastened together with a hinge; this is also the case with all other species of the genus *Teredo* and *Pholas*. The valves are maintained in place by a fold of the mantle in form of an arc (Fig. 1, *b*), which encircles them posteriorly. Moreover, the posterior part of the mantle has a

FIG. 1.

FIG. 2.

prolongation (Fig. 1, *a*, and Fig. 2, *a*) which covers, to a certain extent, the dorsal side of the valves, and extends on each side to their margin, forming two lobes (Fig. 1, *c*, and Fig. 2, *b*), which nevertheless do not adhere to the shell; by this mode of union the relative position of the valves is maintained. With other bivalve mollusks, which do not perforate, this relation is firmly fixed by a hinge; but, with the teredo, the valves have a certain play, which allows a slight displacement in their relative positions. The valves are, moreover, connected by two adductor muscles, which we will soon examine more closely.

The shell presents, even when the valves are brought closely together, three large openings.

The first, on the dorsal face (Fig. 3), is occupied in part by a pallial prolongation, a continuation of which is introduced by this opening into the interior of the shell, in part by the small adductor muscle.

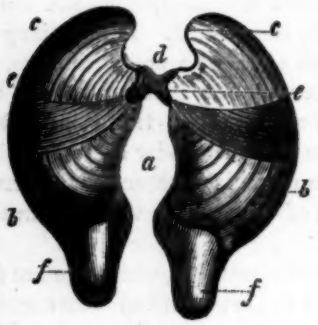

Fig. 3.

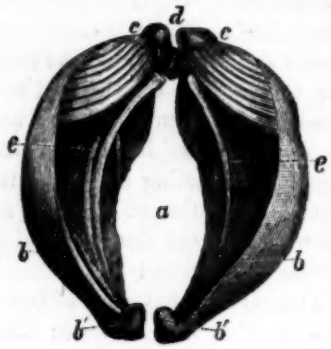

Fig. 4

The second opening is posterior (Fig. 4, *a*), and serves to open a passage to the internal organs contained in the cavity of the mantle.

Finally, the third, placed obliquely in front (Fig. 5, *a a;* Fig. 4, *a*), is the largest, and remains always gaping open to allow the foot to pass out (Fig. 5, *b*).

Each of these valves, which form the shell, is formed of three parts, viz.:

Fig. 5.

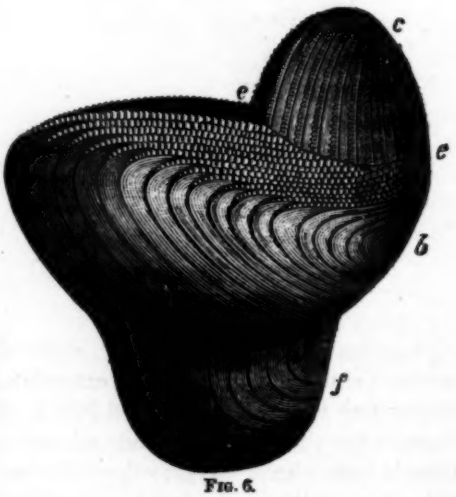

Fig. 6.

1. A posterior part (Fig. 3, *f;* Fig. 6, *f;* Fig. 7 *f*), which we can call the neck part; this posterior is the least arched, and thinner than the rest of the shell: its posterior edge is embraced by the folds of the mantle, which we have already mentioned, and thus the mantle is solidly attached to the shell.

2. The middle part (Fig. 3, *b;* Fig. 6, *b;* Fig. 7, *b*), which is the largest, is strongly arched, and presents, when seen from the side, the form of a half-moon ; its ventral portion is a little more pointed, curved inwardly, and terminated by a small swelling or tubercle (Fig. 4, *b';* Fig. 7, *b'*), which, when the shell is closed, comes in contact with the similar tubercle on the opposite valve.

3. The anterior part, which is a continuation of the upper portion of the preceding part, and is more or less spiral in form (Fig. 6, *c;* Fig. 7, *c;* Fig. 3, *c c;* Fig. 4, *c c*), and its edge makes, when seen from the side (Fig. 6), an angle of a little more than 90° with the free edge of the middle part. The limit of these two parts is marked by a zigzag line, which resembles a sort of suture (Fig. 3, *e;* Fig. 6, *e e*). This part of the shell curves backward and inward, and there terminates in a small rounded tubercle (Fig. 4, *d;* Fig. 3, *d;* Fig. 7, *d*), situated opposite the corresponding tubercle of the other valve. This point is the axis of rotation of the two valves; that is to say, when the shell opens or closes, the tubercles retain their relative positions, while all the other portions of the valves describe about them an arc of circle more or less large.

On each of these tubercles is a short, pointed projection, on which are implanted at about a right angle two other large projections, which extend into the interior of the shell a third or half its length (Fig. 4, *e e;* Fig. 7, *e*). These projections are slightly curved and flattened; they penetrate among the soft parts, so that their inner face reposes upon the visceral mass; their outer face comes in contact with the thin lining or mantle, which covers the interior of the valves and extends to their extreme edge.

Examining the shell with a magnifying-glass, one sees (Fig. 6) a large number of curved lines of growth, parallel, as is usual, with the free margin of the shell ; a closer examination shows that those lines differ in each of the three parts of the valve, although in fact they form a continuous whole.

On the back part of the neck of the valve (Fig. 6, *f*), the lines seem to be simply curved lines without any especial peculiarities. This is equally true of those on the posterior and largest portion of the middle part of the shell (Fig. 6, *b*) ; they seem to be only linear thicknesses ; yet, between each pair of the strongest lines, which are the lines of growth, properly so called, one discovers a multitude of others, much finer, which follow the same direction. Here (Fig. 6, *e e*) the lines of growth form partitions between as many rows of small, sharp, wedge-shaped teeth. Each of these teeth has two rectangular faces on either side of two small triangular faces inclined toward each other (Fig. 8); its cutting edge is placed in the direction of the axis of the animal.

The size of those small teeth varies according to the position they occupy: those which are in the vicinity of the hinge-border are the smallest, those which are on the outer edge are the largest. And, as the part of the shell which is nearest the hinge is the earliest formed,

in fact the only portion which exists at a very early period, it follows that the average dimension of the teeth increases with the size of the shell, that is to say, with the growth of the animal. On a shell, for instance, of 7½ millim. in its largest dimension, where the total number

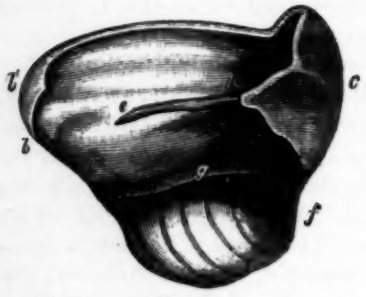

FIG. 7.

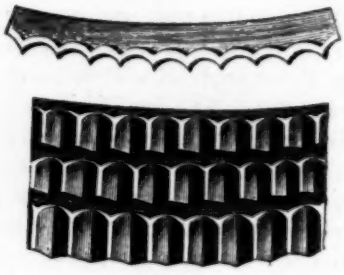

FIG. 8.

of rows of teeth reaches 41, the width of each row near the hinge-part is 52 mmm. ($\frac{1}{19}$ millim.), and the size of each compartment occupied by a tooth is 28 mmm. ($\frac{1}{36}$ millim.), while the same measures, taken on the outer edge of the valve, give 145 and 45 mmm. ($\frac{1}{7}$ and $\frac{1}{22}$ millim.). At this last point the small, wedge-shaped teeth rise to a height of 32 mmm. ($\frac{1}{32}$ millim.) above their common support. On an average, there are in each row about 100 teeth, and consequently more than 4,000 on each valve, and more than 8,000 on the two valves together.

The anterior part, in the form of a spoon, has a similar structure, but still more delicate. The lines of growth form an angle of a little more than 90° with those of the middle part, of which they are a continuation. They appear like small, projecting ribs, the outer edges of which are cut in the form of small teeth pressed one against the other (Fig. 6, *c*, and Fig. 9). These denticles are also in form of wedges; their cutting surfaces are perpendicular to the axis of the animal, and consequently form a right angle with the cutting surfaces of the teeth of the middle part of the shell. But they are much smaller than the latter; their width is only 10 to 15 mmm. ($\frac{1}{100}$ to $\frac{1}{66}$ millim.). Their number is also more considerable, even although that part of the shell is less fully developed than the rest.

On the same shell of 7½ millim. diameter, the number of these denticles is, on an average, 250 on each rib, which makes 10,250 on the 41 ribs, and 20,500 on the two valves.

We should also point out the fact that this spiral part of the shell is evidently composed of more solid matter than the rest of the shell. It has more lustre, and the look of porcelain, and its surface between the ribs is smooth and glossy.

The consideration of the structure which we have related led Mr. Harting to the conclusion that it would be difficult to imagine an instrument better adapted than this shell for boring galleries in wood.

In fact, each valve presents in a certain way a combined auger-bit, gouge, and file. The ordinary steel file is made with two rows of notches, in order that the tool may cut simultaneously in two different directions; in this shell the same end is attained by the two rows of denticles, the action of which is equally in two directions perpendicular to each other; and our shell has another advantage, that it does not foul so readily with the filings as does an ordinary file.

Nevertheless, the winding direction of the galleries, in which it is not unusual to find right angles, or even somewhat acute angles; the defective cylindricity in the form of the galleries, which often appear as if composed of rings piled up one upon another, some larger and some smaller; the form of the end of each gallery, which is always perfectly smooth and hemispherical without any projection in the centre —all these facts show, according to Harting, that the action brought to bear upon wood by the teredo is not that of an auger boring a hole by rotary motion, but rather that of a file; this is rendered more apparent from the results of the careful anatomical study given by Harting to the muscular system of the teredo.

Although confined during its entire life to the dwelling which it has itself constructed, the teredo still has a strongly-developed muscular system. It is evident, moreover, that he uses all his muscles, excepting only those which serve to move the siphons, more or less directly, in the perforation of his galleries.

The first system of muscles is that which one finds in the mantle. That organ is provided through its whole length with longitudinal and

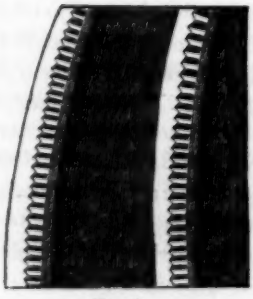

Fig. 9.

Fig. 10.

transverse muscular fibres. These fibres give the teredo the power of elongating or shortening its body; and also, by the partial action of some bundles of fibres, to make a slight movement of torsion.

At the base of the palettes, at the posterior portion of the mantle, is a powerful muscular ring (Fig. 10, *c*); by means of this ring, when

the posterior extremities are expanded, the siphons (Fig. 10, *e* and *d*) can be carried outside into the water; at the same time the access of the two siphons, and consequently the entrance and exit of water, can be more or less hindered. As we have seen, the mantle is prolonged in the direction of the shell in an appendage which extends over the two sides of the dorsal surface of the valves (Fig. 1, *a*, and Fig. 2, *a*), the central portion of which forms a swelling of considerable thickness, composed of various anatomical elements; beneath the epidermis the tissues are partly of vesicular and partly of membranous character, which, through inherent powers of swelling and hardening under the action of the blood, serve a purpose in operating the movement of the valves.

To explain the physiological *rôle* of this organ (*a*, Figs. 1 and 2), it is necessary to recall the fact that it receives on either side, in the arched folds of the mantle, the neck-portions of the valves of the shells. By the contraction of the bundles of muscular fibres, the two valves would separate slightly one from the other, a movement which is still better understood if it is proved that that organ can become hard by the afflux of the blood and thus furnish a better fulcrum for the action of the muscles. Up to a certain point this part is similar to the hinge-ligament of other bivalve mollusks; but only in this respect, that it serves to open the shell. For the true ligament, wherever it exists, is always composed of elastic tissue, and its action is purely passive, while with the teredo the opening of the shell is a muscular action and consequently active. Moreover, the hinge is wanting in this case, which allows the supposition that the animal has the power of modifying at will, by the partial contraction of its muscles, the direction in which the valves separate, so that it may be at one time the middle parts and at another the anterior parts of the valves which separate most from each other. Besides, the effort which this action demands is extremely feeble, and the movement of the valves themselves is very limited.

There are two adductor muscles. The first and largest is already well known; it has been described by all writers who have made the teredo an object of study. It extends (Fig. 11, *m*) between the two valves in the form of a muscular mass, relatively quite large, and occupies about two-thirds of the length of the shell and one-third of its width. It rests on either side on a sort of pad situated at the limit between the middle and neck parts of the valve. The second or small adductor muscle, which appears to have escaped the attention of most observers, is found near the dorsal side of the shell in the cavity between the anterior portions of the valves. One can see its exterior surface, clothed with a thin epidermis and slightly projecting immediately in front of the pallial prolongation, which extends over the dorsal face of the shell; in appearance it is only a continuation of this muscle, but in reality it is entirely distinct.

The principal mass of this muscle is implanted upon the sides, bent

backward within the anterior, spiral parts of the valves (Fig. 11, *p*) below the line which passes by the two tuberculous extremities, coupled together, i. e., by the centre of rotation of the valves. From this principal mass some slender muscular fibres extend over the two thorny protuberances (Fig. 11, *e e*), which may be compared to two arms of levers, whose common fulcrum is found in the centre of rotation of the valves. It is clear that, by this arrangement, the action of the muscle is considerably strengthened.

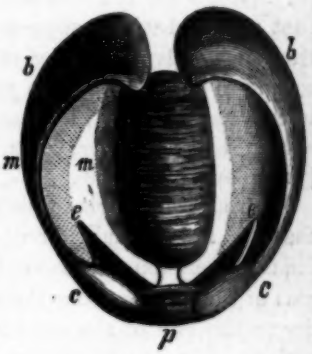

FIG. 11.

The two adductor muscles are composed of the same microscopic elements, that is, of fibres and fibro-cellular tissue, easily separated in form of a ribbon, six mmm. wide and one mmm. thick; their length is relatively considerable, and probably equal to that of the muscles themselves, inasmuch as one can nowhere discover any free extremities. These fibres are distinguished from the fibro-cellular tissue of the mantle not only by their greater length, but also by their darker outlines, which indicate thicker walls and, consequently, greater solidity and strength.

The effect produced by these muscles in contracting is very evident. The large adductor muscle, situated on a plane a little above the general centre of rotation of the valves, serves to draw together the rounded sides of the valves as well as all the other parts of the valves situated posteriorly on the same side of the centre of rotation. The small adductor muscle, placed in front of the centre of rotation, exercises a more limited action. When it contracts, the anterior extremities of the spiral part of the valves approach each other; simultaneously, all the parts of the shell situated behind experience a slight displacement forward, as if they tried to turn about an axis passing by the centre of rotation; but the one which they thus describe is necessarily very small, on account of the shortness of the muscle. It is evident that the direction of the movement made by one of these adductor muscles is nearly a right angle with that of the other; the anterior and middle parts of the valves, which are first acted upon by the action of the muscles, meet at an angle of 90°.

Finally, the teredo has also a muscular organ, without which it would be impossible for him to pierce his galleries. It is the part known as the foot, which has the power of projecting outside between the anterior opening of the valves (Fig. 5, *b*; Fig. 1, *d*—the dotted line indicating the outline of the foot in the state of extension). This foot has the power of extension and retraction, and terminates at the end with a suction-disk, by the aid of which the animal can attach itself to the wood.

From what precedes, it is evident that the teredo, far from being,

as Deshayes has pretended, an animal having very few if any muscles, is, on the contrary, richly provided with those organs. There are the longitudinal and transverse muscles through the whole length of the mantle, a true sphincter (Fig. 10, *c*) at the base of the siphons, a muscular organ which receives and covers a part of the valves, two adductor muscles for the movement of bringing the valves together, and a foot provided with a suction-disk and susceptible of extension and retraction—truly a profusion of motive organs which one would not expect to find in an animal which passes its entire life in a narrow canal which it can never quit. Moreover, all these motive powers have only one essential end, namely, to endow the teredo with the power of boring his gallery—his home.

But all the muscles which we have enumerated do not coöperate to that end in an equally direct manner. When water has entered by the incurrent siphon, the animal can, by contracting the transverse muscles of the mantle, force the water through the whole length of its body up to the end of the gallery, and then drive it out by the excurrent siphon. The teredo undoubtedly makes use of this as a means of getting rid of the fine filings of wood which the valves of the shell have detached. He can then draw back a little the anterior part of his body by the action of the longitudinal muscular fibres, supporting himself by the two palettes pressed against the inner walls of the calcareous tube at a distance of two or three millimetres from the exterior opening, by which the siphons project outside the wood. It is probable that the teredo takes that position during his periods of repose, which come from time to time, and which he uses for repairing his tools.

The teredo possesses, on the other hand, the means of preventing or hindering the outflow of water at will, so that its body, distended by the liquid, occupies at that time the whole extent of the gallery, and his anterior portion touches with the valves of its shell the end of the gallery. In this position he can carry on his work of miner. He commences then by extending his foot (Fig. 1, *d*), which he fixes by suction against the side of the cavity. At the same time the valves separate a little; then, while the foot draws the shell to itself and thus presses its exterior surface against the wood, the valves close up again, and the denticles with which they are furnished cut into the wood.

In this labor there are still two peculiarities worthy of notice: First, the limited extent of movement with which the valves are endowed, their anterior extremities moving only a very short distance from each other. But this circumstance, in view of the narrow space in which the teredo works, gives him this advantage, that, by the rapid succession of movements of opening and closing the shell, he attains his end—namely, to reduce the wood to an impalpable powder—better than if each blow of the instrument had a wider range. In the second place, we should recall the fact that the directions of movement of the two adductor muscles are at right angles, as are also the directions of the cutting surfaces

of the denticles on the two parts of the same valve. Hence it is clear, after the description which we have given above, that if the large adductor muscle contracts, the denticles of the anterior or spiral part of the valve cut the wood; if, on the contrary, the small adductor muscle is shortened, it is the middle part of the valve which undergoes a movement of rotation, and the teeth which it bears are set at work. Thus, then, whether the two muscles contract simultaneously or one by one, the woody cells are cut by successive incisions, which would divide them into small quadrangular pieces, if there be no rending of the fibres. It is evident that the hardest task is demanded from the spiral part of the valve, for it is that part which is first brought to bear upon the wood. This part also has a more solid structure and the denticles are much finer; it is moved by a muscle of considerable size; the power of this muscle is, moreover, sensibly increased by the fact of its being implanted upon the two middle parts of the valves, each of which can be considered as a long arm of a lever whose extremity passes over a space at least four times as large as the portion of the valve which, strictly speaking, does the work.

The foot remains fixed in the same spot a very short time only. The form of the end of the cavity, that of a regularly rounded basin, suffices to prove that the valves of the shell are placed every instant in contact with a different spot. The foot displaces itself, little by little, so as to give a rotating movement to the shell, and at the same time to all that part of the body beyond the shell, even as far as the palettes. When the torsion thus produced becomes excessive, the foot loosens its hold, and the body returns to its former position. Thus, then, the rotary movements remarked by some observers, far from being the cause, should be considered rather the effect; they are only the shifting of position of the animal, and nothing more.

The teredo does not bore out his galleries, but he hollows them out with an action analogous to that of a file, by means of the thousands of cutting teeth with which its valves are armed. If the teeth do not break away rapidly, it is due to their wedge-like form and to the oblique direction of the planes which bound each of these wedges. Moreover, as the animal grows, new rows of teeth are formed, so that the rows which have served in youth are no longer of any use in more advanced age; they are principally the outer rows of teeth, the last formed, which do the work.

The sense of touch exists in the teredo in the suction-disk. This is not only a muscular organ, but one rich in nerves. Quatrefages has already pointed out the two small ganglia, situated on the intestines, which furnish the nerves for that part of the body. The foot, when extended, commences by feeling the place before attaching itself to it and drawing the shell after it. Naturally, it avoids the places which seem to offer too much resistance; but he avoids with equal care the parts where there only remains a wall of wood too thin for sufficient re-

sistance. In this case, in fact, the gallery is approaching either the surface of the wood or a neighboring gallery; a teredo is never known to destroy the work of another; that, moreover, would not serve him, for, even should he perforate the woody division between them, he would drive against the calcareous tubes, which, being scarcely less hard than the valves themselves, cannot be attacked by them. Whenever the teredo encounters an obstacle, he simply turns aside; he acts like the mole, which, excavating her trenches by preference in a rich loam, makes a *détour* around the stones which she meets in her way, and changes her direction when she comes near the breast of a ditch, to avoid the open air.

I will state, moreover, that the conclusions regarding the manner in which the teredo perforates his galleries, deduced at first by Harting from the anatomical examination of his organs, have since been fully confirmed by direct observation; Kater, having opened laterally one of the galleries, so as to partially expose the animal, has seen him at work, executing all the movements above mentioned.

[*To be continued.*]

ON THE DREAD AND DISLIKE OF SCIENCE.

By GEORGE HENRY LEWES.

IN the struggle of life with the facts of existence, science is a bringer of aid; in the struggle of the soul with the mystery of existence, science is a bringer of light. As doctrine and discipline its beneficence is far-reaching. Yet this latest-born of the three great agents of civilization—Religion, Common-Sense, and Science—is so little appreciated by the world at large that even men of culture may still be found who boast of their indifference to it, while others regard it with a vague dread which expresses itself in a dislike, sometimes sharpened into hatred.

I shall be told, perhaps, that the growing demand for popular expositions of scientific results and the increasing diffusion of scientific inquiry point to a different conclusion. It is true that there never was a time when science was so popular. It is true that every year the attendance on lectures and the meetings of scientific associations is larger. The tide is rising. The march of Science is bit by bit conquering even the provinces which most stubbornly refuse allegiance to it. But, meanwhile, among the obstacles it has to overcome are certain prejudices and misconceptions which are the grounds of a deep-seated dread. No better illustration can be given of the general suspicion and dislike of science as science than the great stress which is laid on the "iniquity of vivisection," *because* experiments on animals are pursued for purely

scientific purposes. The animating impulse of an effort to awaken a due sympathy with animal suffering and check an inconsiderate infliction of it is one which so entirely commands my esteem, that I would willingly overlook the flagrant contradiction of people tolerating without a murmur the fact that yearly *millions* of creatures are mutilated and tortured to give a few men pleasure, to make food more palatable, and domestic animals more tractable, yet are roused to fury by the fact that a few *score* creatures are mutilated (a smaller number tortured) to discover remedial agents and scientific truths. All the pain inflicted for sport or other pleasure is condoned; the pain inflicted for scientific ends is pronounced diabolical. Is it, therefore, not on account of the suffering inflicted, but on account of the scientific purpose, that vivisection is to be reprobated? Ten thousand times the amount of suffering is disregarded if only its purpose be *not* that of acquiring knowledge. And that this is so, is manifest in another case. For suffering may be also inflicted on human beings, and on a large scale, without exciting any outcry, if the motive be commercial advantage. Not to mention wars undertaken to push commerce, let us only consider some industrial experiment which will certainly drive hundreds of families from their employment with starvation as the consequence; yet the sufferings thus occasioned, if they excite pity, weigh so little against the prospect of the general good, that if the starving workmen revolt and destroy the machinery, the philanthropist is ready to enforce on them the utmost rigor of the law. Here the social benefit is allowed to override the individual injury. That is to say, an experiment which has the prospect of enlarging *wealth* may inflict suffering on men, women, and children; but an experiment which has only the prospect of enlarging *knowledge* must be forbidden if it inflict suffering on animals! Obviously such a contradiction could not be upheld if science were recognized as a social benefit. It is not so recognized. And one indication of this is the frequent accusation that physiologists are actuated by the "selfish motive of acquiring reputation," not by the unselfish motive of benefiting mankind. I will not pause to discuss the question of motives, nor how far the selfish motive may further a social advantage; I will only ask whether the motive of the industrial experimenter is less selfish? Unless science were a social benefit, no one would ardently desire a scientific reputation.[1]

Having indicated the existence of the dread and dislike of science, let us now glance at the causes.

The primary cause is a misconception of what science is. No rational being dreads and dislikes knowledge. No one proclaims the

[1] When one observes those who believe hospitals and colleges to be important institutions, socially beneficial, threatening to withdraw all support unless the teachers openly declare what they do not believe, namely, that vivisection for scientific ends is unjustifiable, one is reminded of the recent outbreak of fanaticism on the part of the Jains. This Hindoo sect has such a horror at the destruction of animal life that a group of the most fervent murdered all the Mussulman butchers in the neighborhood.

superiority of ignorance as a guide of conduct. Yet science is simply knowledge classified, systematized, made orderly, impersonal, and exact, instead of being left unclassified, fragmentary, personal, and inexact. Auguste Comte calls it "common-sense methodized and extended." There is plenty of knowledge which is not exact, and of exact knowledge which is not methodized. There is plenty of experience which is personal and incapable of being communicated to others. Wanting the illumination of many minds, this store cannot do the work of science, which is the experience of many enlarging the experience of each. If there is immense benefit in knowing what are the facts and the order of the physical world in which we live, and of the social world in which our higher life is lived, there is clearly a great advantage that this knowledge should be made orderly and communicable; and the dread of such an arrangement of knowledge is obviously irrational. Thus enlightened, we recognize in science the deliberate effort to reduce the chaos of sensible experiences within the orderliness of ideal constructions, condensing multitudes of facts into simple laws—an effort which the intellect acknowledges as a supreme duty, and which conduct acknowledges as a guide.

Another source of the dislike is the opposition of our native tendencies. Science is abstract, impersonal, whereas our experiences are concrete and personal. It is systematic, and systematization is troublesome: our native indolence renders us impatient of labor, and our impatience leads us to prefer the facile method of *guessing* to the difficult method of *observing:* we have to be trained into the preference of observing what the facts are, instead of arguing as to what the facts must be. Science, moreover, is greatly occupied with remote relations; now, to feel an interest in these we must first have had them "brought home" to us. Knowledge springs from desire. It begins when prolonged *observation*, stimulated by emotion, replaces the incurious animal *stare* at things; and for this prolongation there is needed a sustaining motive. The sustaining motive of research is the conviction of the vast increase of our power which science creates. Measuring by a foot-rule and measuring by trigonometry may be taken as types of common knowledge and science: the result reached may in some particular case be the same, whichever method be used; but the incomparable extent of the second method, which is applicable where the foot-rule cannot reach—which measures the heights of mountains and the distances of stars—furnishes the sustaining motive to the study of trigonometry.

Science demands exactness, and this demand irritates the vulgar mind. The impatience with which your cook listens to your advice that she should measure and not guess the quantities (advice you can never get her to follow) is but the same movement which rouses your resistance when any one desires to test your opinions by weighing the evidence, or endeavors to show that your traditional beliefs rest on no verifiable observations. Is not he who insists on evidence commonly

styled "a bore" by all whose opinions have been adopted quite irrespective of evidence? Is it not pronounced "narrow" to hesitate in accepting wide conclusions without a keen appreciation of their data?

The distaste for accuracy, and the impatience at any restriction of the divine right of judging without evidence, will disappear with the advance of knowledge; and with this advance will also disappear certain mistaken pretensions of scientific men too ready to step beyond their own domain. It is this which causes the distaste of artists, men of letters, and moralists; and their opposition to the spread of scientific teaching. They do not oppose knowledge in the abstract, nor any particular knowledge; what they resist is the idea that the conclusions reached in one department of inquiry are to dictate conclusions in another. The artist is quite willing to accept the chemist's methodized experience of chemical facts, but refuses to listen to the chemist theorizing about art. The moralist will accept from the physicist equations of light, and from the anatomist relations of structure; but reserves to himself the right of deciding on a moral question.

One must admit that in the inarticulate resistance of sentiment and common-sense against certain applications of scientific doctrines there is often a justification. For example, there are mechanical laws and equations which admirably explain the facts of motion, yet sentiment is shocked at the attempt to explain Nature on mechanical principles only, and is sustained by common-sense, which sees other facts besides facts of motion, and sees that Nature is not mechanical only. Again, when the stored-up wealth of sentiments laboriously evolved in civilized life is set aside in favor of some analogy drawn from observed processes in the inorganic world, when the moral impulse to cherish the weak and sickly is condemned because Nature (which is *not* moral) cherishes the strong and pitilessly destroys the weak, common-sense protests, and the protest helps to intensify the popular distrust of science. Yet, in truth, the wiser heads among men of science are equally alive to the mistake of such applications.

What is to be understood by Science? It means, first, a general Method, or Logic of Search, applicable to all departments of knowledge; and, secondly, a doctrine, or body of truths and hypotheses, embracing the results of search. In this second acceptation there are the particular sciences—such as mathematics, physics, chemistry, biology, psychology, etc.—which are the special applications of the general method to special departments of knowledge; and although there is an interdependence of these sciences, each is restricted to its own class of facts, none can legislate for the others. But because the various branches of knowledge have been very unequally reduced to the exactness and orderliness of science, those which have been most successfully reduced have acquired the almost exclusive title; so that science is generally regarded as something apart—the peculiar study of a particular class.

Hence also the opinion that there is a profound separation between the principles applicable in the physical sciences and the principles applicable in the moral sciences. What has been the consequence? It has been that the method which is no longer regarded as a rational procedure in dealing with the phenomena of Nature is followed without misgiving in dealing with the phenomena of human nature; and the supernaturalism long banished from physical theories is still invoked in psychological and social theories.

Of late years this has ceased to be the universal error, though it still remains a wide-spread error. We are slowly beginning to recognize that there may be a science of History, a science of Language, a science of Religion, and, in fact, that all knowledge may be systematized on a common method. The facts of the External Order, which yield a cosmology, are supplemented by the facts of the Internal Order, which yield a psychology, and the facts of the Social Order, which yield a sociology. These are all comprised in science. However imperfect the second and third may be, in comparison with the first, the greater complication of the phenomena does not warrant the introduction of another Logic of Search. The principles which have guided us successfully in the first are to be followed in the others. The three classes of facts are all facts of experience, so far as they are known, and must all be tested, classified, and systematized, by the same rules.

This being so, we can separate the rational from the irrational antagonism against science. It is rational when protesting against the misplaced application of the results reached in one department to problems belonging to a different department—for this is an offense against scientific method. It is irrational when protesting against the rigorous application of one logic to all inquiries. Those, therefore, who sneer at science, and would obstruct its diffusion, are sneering against the effort to make all knowledge systematic, and are obstructing the advance of civilization.

The notion, implied or expressed, of two Logics, two Methods of Search, two systems of explaining phenomena, the natural and the supernatural, is the foundation of the great conflict between Science and Theology. And since, in the majority of minds, theology is identified with religion, and religion is of supreme importance to man, it is natural that science should be regarded with dread and dislike. Before proceeding to dissipate the confusions on this subject, it will be needful to glance at the attitude of sincere theologians in our day, and at the reasons which justify to their minds the acceptance of scientific doctrines side by side with the acceptance of theological doctrines. It would be equally ungenerous and short-sighted to suggest that a mind which is deeply impressed with the truth of certain theological opinions may not be also deeply impressed with the beneficence of science in general, and the truth of scientific doctrines which do not directly embrace moral and religious questions. We have too many conspicu-

ous examples of men eminent in science and sincere in their theological professions, not to admit that the mind *can* follow two logics, and can accept both the natural and the supernatural explanations. Whether the mind *ought* to do so, is another question. Let no one, therefore, suspect me of a doubt as to the sincerity of theologians who proclaim that the sphere of science is limited to the processes of the physical world, and may be frankly accepted in all that it teaches respecting such processes, without in the least involving the moral world, or in any way affecting the truths respecting that moral world which theology derives from a source independent of experience. Science, they say, systematizes whatever experience reveals; its test is Reason. Theology systematizes what had been revealed from a higher source; its test is Faith. Between reason and faith there is an absolute demarkation; and between science, which relies on observation and induction, and theology, which relies on precept and intuition, there is no conflict. As the artist appeals to the chemist for a theory of salts, and to the mathematician for a theory of singular integrals, but declares both chemist and mathematician to have no voice in a theory of art, so the theologian accepts the teaching of mathematician, physicist, chemist, and biologist, in their respective departments, but peremptorily excludes each and all from the supreme department of moral and religious duties founded on a theory of the relations of the world to its Creator.

Thus stated, one must admit a sufficient logical consistency in the present condition of compromise, and need suppose no kind of insincerity, no conscious equivocation in the acceptance of both the natural and the supernatural modes of explaining phenomena. Nor, indeed, could the fundamental inconsistency of such a compromise have been even recognized, until the quite modern extension of scientific method to moral questions had come to complete the disintegrating effects of historical and philosophical criticism applied to the sacred books on which theology relied. In the earlier stages of development, although the natural explanation was adopted in reference to the most familiar experiences, and framed the rough theories of common-sense for the habitual guidance of conduct, both in relation to the physical world and to society, the supernatural was adopted in reference to whatever was unusual and unseen; and the wider range of this speculative method was due to the immensity of ignorance. The slow progress of positive knowledge has more and more enlarged the domain of natural explanation, more and more restricted the domain of the supernatural. Yet, even now, the majority of cultivated men regard the facts of human nature as only partly explicable without aid drawn from the supernatural; and resist, as impiety, the attempt to assign natural causes in explanation of moral relations. That is to say, there where the operation of natural causes escapes our penetration, supernatural causes are invoked. Just as to men, ignorant of natural conditions, thunder was

the fury of the storm-demon, or an eclipse was God's anger, so nowadays men, ignorant of natural conditions, interpret epidemics as "visitations," and regard "intuitions" as of divine origin. The inconsistency, then, of the acceptance of theological side by side with scientific principles, is only a continuation of the primitive mental state, and must vanish when there is a general conviction that science is orderly knowledge, and is coextensive with experience. If we can have no knowledge transcending experience in the widest sense, and if faith is the vision of things unknown—dealing with what transcends knowledge—then the conflict between science and theology is the conflict between knowledge and ignorance.

Unless this be the character of faith, I dispute the claim of Theology to the exclusive possession of faith as a principle of guidance. Science also has its faith, and by it must all men to a great extent be guided. But the faith of Theology and the faith of Science are very different in their *credentials.* The former is the reliance on the truth of principles handed down by tradition, of which no verification is possible, no examination permissible; the latter is reliance on the truth of principles which have been sought and found by competent inquirers, tested incessantly by successive generations, are always open to verification in all their details, and always modifiable according to fresh experiences. We believe in the law of gravitation, though we never opened the "Principia," and could not, perhaps, understand it; but we rely on those who can understand it, and who have found its teachings in harmony with fact. We believe in the measurement of the velocity of light, though ignorant of the methods by which the velocity is measured. We trust those who have sought and found. If we distrust them the search is open to us as to them. The mariner trusts to the indications of the compass without pretending to know how these indications were discovered, but assured by constant experience that they guide the ship safely. That also is faith.

But if the mental attitude is one of the same obedience as the theological faith, its justification is different. Its credentials are conformity with experience. Those of theology are the statements of the sacred books: the Vedas, Zendavesta, Bible, Koran. The statements therein made concerning the divine nature, its relations with the human, and the providential government of the world, are not open to the verification of experience, for they were not sought and found in experience. If we ask for their credentials, we are told that they are of divine origin. If we ask for evidence of this divine origin, we are referred to history or to our moral consciousness. Tradition has handed down these statements through successive generations; yet if we ask, as we ought to ask, how the tradition itself originated, we are brought face to face with this twofold difficulty: we cannot recognize that those who first promulgated the statements *had any better means of knowing the truth than we have;* and we are struck with the fact that the statements thus

handed down by tradition do not agree. That of the Hindoos is not that of the Jews; the Persians reject the traditions of both.

Modern historic criticism has made such havoc with the historical pretensions that theologians are now throwing all the emphasis on moral consciousness. The doctrine of our sacred books is said to be unequivocally ratified by our intuitions: we feel their truth, and we see in their moral influence on mankind the verification of their divine origin. But here again the scientific method, which applied to the historical evidence has shattered its claim, applied to the evidence of moral consciousness is equally destructive. Psychology not only enlightens us as to the genesis of the intuitions, but, in a comparison with other nations and the earlier stages of human development, shows how they vary. If the intuitions of the savage are not those of the civilized, if precepts which the Hindoo feels to be divine are opposed to precepts which the Chinese, the Jew, the Mohammedan, and the Christian, feel to be divine, we need a criterion beyond these varying standards.

There is a wide-spread superstition which regards whatever is innate, or otherwise unexplained, as of a higher authority and diviner sanction than what is acquired through individual experience or is explicable on known laws. Our religious instincts are appealed to, as if instinct were the infallible guide in conduct; although a moment's reflection will show that it is the great aim of civilization to correct and repress many instincts. If the developed music of our day is of a higher order and more adapted to our sensibilities than the music of the middle ages; if our theories of natural phenomena are of a higher order and approximate more nearly to the truth than the corresponding theories of Aquinas and Albertus Magnus, why should our theories of moral phenomena be deemed inferior to those of Judaism or the councils? Is the nursery a school of riper wisdom than the laboratory?

So much as to method; now as to results. The sacred books of all theologies claim to expound a theory of the universe and a theory of human life and destiny. Their theories of the universe, both as general conceptions and particular explanations, are in such flagrant contradiction with the teachings of Science, that nowadays no one who is worth a moment's consideration seeks astronomical, geological, or physiological explanations in the sacred books. There has arisen the assertion that the sacred books were never intended to teach man scientific truths, but only to teach him his duties. The answer is twofold: first, that man's duties are comprised among scientific truths; secondly, that the books *do* teach, not scientific truths, but doctrines which science shows to be erroneous. We ask, therefore, if their dicta are proved to be erroneous on points where the control of observation is possible, what authority can they claim on points beyond all such verification? If their astronomical, geological, and biological statements are false, why are we to believe their statements respecting the origin of the universe, the laws of its evolution, the nature of man, and the conduct of man?

The escape from this dilemma which is attempted by giving up the physical world to science, reserving the moral world for theology, is only a temporary escape. Let it be granted that the authority of the sacred books refers solely to to the phenomena of human nature in the double aspect of the relations of man to God and his relations to society. If they contain explicit statements which are at variance with our moral culture—such as that God is "jealous" and "vindictive," or that sinners will be consigned to everlasting torment—they must have some other guarantee of their truth than the ratification of moral consciousness, since that rejects them; and if they contain statements respecting man's nature which are at variance with experience when they can be verified, how shall we accept their authority when the statements are beyond verification?

When the statements are ratified by experience and moral culture, theology can give these no *extra* sanction; when they are not so ratified, theology cannot make them acceptable. By way of illustration of the conflict between Science and Theology, in their explanations of human phenomena, with the precepts which are founded upon each, let us take the case of disease.

Very little is accurately known of its causes; but whatever they are, science, recognizing disease as the result of some disturbance of the organic functions, seeks the unknown causes in the known properties of the substances composing the organism. Theology, which uniformly explains the unknown by the unknown, invokes a supernatural cause for this natural effect. It declares that God sends diseases as chastisements and lessons. Nor is this declaration withdrawn when common-sense objects that the chastisement is often an injustice and the lesson an enigma. The innocent are seen to suffer even more than the guilty, and no one knows why they suffer; no one can regard the punishment of the child for the sin of its father as in agreement with human justice. But you say, "All men are guilty?" Then why are not all punished? And why are animals and plants also afflicted with diseases? Have they, too, the burden of Adam's disobedience? There was a time when such explanations reconciled the doctrine with observation; but nowadays cultivated minds shrink from the conception of "imputed sin" as a rational explanation of human and animal suffering.

In applauding this progress we must also point out the logical inconsistency of those who maintain the absolute authority of the texts of which such conceptions are the necessary applications. Theology maintains its doctrine even when theologians set aside the practice which that doctrine ordains. To claim absolute submission to the physician's formulas, and yet refuse to follow his prescriptions, is surely irrational? Yet this is the case nowadays. When the supernatural theory of disease was undisturbed by positive knowledge, prayers and incantations were the remedies in vogue; but now even those who will not acknowledge the theory to be an antiquated error practically disa-

vow it, for they replace prayers and incantations by drugs and diet. Only the small sect called "The Peculiar People" trust entirely to prayer; and Christian magistrates are so outraged at this trust that they punish it as a crime! In vain are epidemics declared to be visitations, in vain are books written with such titles as "God in Disease;" the practical sense of the nation decides that cholera or cattle-plague are not to punish landlords and farmers for the skepticism of a few speculative minds, and hence that we had better seek to avert them by a course of treatment and "an order in council," than by pulpit eloquence and a "day of humiliation."

I have taken the case of disease because it is less open to the ambiguities and difficulties which beset a moral problem, but a similar discrepancy might be pointed out between the theological precepts and the moral practices. Here, as everywhere, it is patent that as knowledge advances, theology loses its hold; and morality, instead of remaining stationary like theology, advances with an enlarging insight into the healthy conditions of human relations. Science is often taunted with its imperfections and its inability to explain the mysteries of life. Imperfect it is, and that is why we should all strive to make it less so. Mysteries will doubtless forever encompass us. But Science may answer the taunt by challenging Theology to show that its explanation of the mysteries has any claim to our acceptance. The question is not whether *an* explanation can be given, but whether the given explanation has any verifiable evidence. Kant has truly said that now criticism has taken its place among the disintegratory agencies, no system can pretend to escape its jurisdiction. The Church has its texts, and has decided once for all what meaning these texts must bear. But the criticism of scientific method asks for the evidence which can prove these texts to be of divine origin, and the evidence which can prove these interpretations to be in agreement with fact. In both respects the answer is unequivocal. There is no evidence to prove the texts. The interpretations are discordant with experience. Thus the Catholic who accepts Galileo and Newton must give up the texts, or take the first step toward Protestantism, which asserts the right of interpreting the texts according to private judgment. And the Protestant who asserts this right of interpretation, and forsakes the literal meaning of the texts, has taken a step toward rationalism, and implicitly disavowed the authority of the texts, since what he obeys is not their teaching, but the teaching of the culture of his day and sect. The rationalist, in turn, has taken a step toward the scientific position; he regards the texts as symbols of an earlier stage of culture, which need the interpretation of our present culture; and when he learns—as easily he may learn—that all the facts of the moral world are to be investigated and systematized on the same principles as the facts of the physical world, setting aside in the one as in the other all supernatural and metempirical conceptions, because these cannot enter into the framework of

knowledge, he will learn that science, in the true meaning of the term, embraces Nature and human nature, and moreover that it expresses what is *known* of both, whereas theology is only "the false persuasion of knowledge."

Many readers may vehemently deny the assertion just made. They will maintain the validity of theological explanations, all the more because, persisting in the old confusion of theology with religion, they refuse to acknowledge that a science of Nature and human nature, if truly expressing the facts, must be a better foundation for religion than a theology which untruly expresses those facts. The whole contest lies between the two modes of explanation and the results reached by such modes. I accept the appeal to history. This shows how, in proportion as knowledge became exact and orderly in each department of inquiry, the supernatural and metempirical explanations were silently withdrawn in favor of natural and experimental explanations. Nowadays, among the cultivated minds of Europe, it is only in the less-explored regions of research, where argument is made to do duty for observation, that the supernatural and metempirical explanations hold their ground. When science has fairly mastered the principles of moral relations as it has mastered the principles of physical relations, all knowledge will be incorporated in an homogeneous doctrine rivaling that of the old theologies in its comprehensiveness, and surpassing it in the authority of its credentials. "Christian ethics" will then no longer mean ethics founded on the principles of Christian theology, but on the principles expressing the social relations and duties of man in Christianized society. Then, and not till then, will the conflict between Theology and Science finally cease; then, and not till then, will the dread and dislike of science disappear.—*Fortnightly Review.*

CURIOUS SYSTEMS OF NOTATION.

By T. F. BROWNELL.

THERE is no example of a people without a system of numeration. The rudest savages manage to count to some extent. The attempts of many of them, however, do not succeed with numbers greater than three or four. With increasing knowledge, they learn to count larger numbers, but the process is a slow and troublesome one. It is performed in all cases by the use of the device of grouping. All systems of numeration that are known consist of this device. In the first stages, the groups are all of the first and lowest order. The savage, counting from one to five upon his fingers, closes his hand to express five; then he again begins counting upon his fingers to form a second group; and he continues to form groups of five to as great a number

of groups as he can express. But all his groups are of the first order, and consist of units. He must make great advance in intelligence before he can take the next logical step in counting, by grouping the groups of five and then indicating these groups of the second order by a symbolic act.

In nearly all instances the method of grouping connects itself with the number of fingers on one or both hands, or the number of fingers and toes. Classification by pairs is also common. This is the simplest method, and was probably the first that was used. It arose, without doubt, from the common use of the hands in separating and combining articles in pairs. But the bases found most commonly in use are five, ten, and twenty. So universal is the selection of these numbers, that systems founded upon them have been termed the natural systems. There can be no doubt that the use of them arose from the number of fingers and toes. But, as has been said, these systems are natural only in the sense that ignorance is natural. They originated among the most ignorant races, without alphabet or figures. They were selected in crude attempts by unlettered savages to count game, or the days as they passed. The fingers formed the most convenient counting-board, and were therefore used.

The number of the fingers upon one hand was probably used in counting before the device of using the number upon both hands was thought of. In many of the Oriental languages the name for five means also hand. Vestiges of a scale of five are found in the decimal systems of many countries.

But the quinary system usually passes into the decimal for numbers above twenty, and frequently at some higher point into a third system in which twenty is a basis. Some of the Celtic dialects present a strange mixture of the three. The French language shows the vicinary scale in parts of its notation, and the use of this scale is much more common than is usually supposed. The Greenlanders give to twenty a name which means "a man." Our word "score" is probably a vestige of this scale. Its use was at one time very common for numbers between sixty and one hundred, where a similar counting now obtains in French. There can be little doubt that our Teutonic ancestors formerly used the vicinary scale for a portion of their counting. There are other instances where the vicinary has preceded the decimal system; but there is no example where the twenty scale has been carried to groups of the second order. Usually, like the five scale, it has been superseded by the denary system, which is now universally used.

With devices for numeration, there have been developed different systems of notation. By these, the attempt has been made to express numbers by written signs or symbols. As a general rule, practical methods of numeration have preceded the use of written symbols. The different systems of notation which have been developed and used, exhibit different degrees of excellence. The Greek and the Roman

systems need no description. The Hindoo notation now in use, which superseded the Roman, differs from those which preceded it in many respects, all of which are to its advantage. It requires only nine symbols, together with the dot or zero. Its chief excellence, however, arises from its principle of "local values." Each symbol has two values: one intrinsic, and the other local. The intrinsic value is that which the symbol has when it occupies the unit place. Thus, the nine significant digits express the numbers from one to nine. The local value is that which a digit derives from its position in the number to which it belongs. Thus thirty is expressed by 30, the 3 by being thrown into the second place obtaining a positional value which is ten times greater than its absolute value. Since this increase is tenfold, the system is called decimal. If the figures are removed one place farther to the left, their value is again increased tenfold, and a like increase obtains for each removal. If removed to the right, their value is decreased ten times for each place of removal. The number by which the positional value changes is termed the root or radix of the system. It is one of the advantages of this notation that it enables us to express numbers with great ease, but its principal advantage appears in the simplicity which it gives to computations of all kinds. Another peculiar merit appears when fractions are involved, in the facility with which "decimal" fractions may be used.

But the merit of the Hindoo notation does not arise from the fact that it is decimal, but from its system of "local values." Ten was used as its radix simply because that number happened to be the basis of numeration universally in use when the notation was invented. Any other radix might have been used, since the principle of local values may be applied to all numbers. It has not, however, been popularly applied except to the number ten. Discussion, however, has arisen from time to time as to the merits of the number ten in comparison with other numbers. It appears to be admitted by all who have considered the matter that ten is far from being the best number for the purpose. It would be remarkable if it were. It came into use not on account of any intrinsic excellence, but because the number of the fingers is ten. For no other reason, ten was the number of objects placed in each group when the device of grouping came into use; then, naturally, it became the basis of the early systems of notation, and when the Hindoo notation was invented, it was taken for the radix of that system. It evidently was not selected on account of its fitness for the position. Were we eight-fingered, we should without doubt perform all our calculations with a scale of eight, to our great advantage in all arithmetical work.

Ten is, theoretically, ill suited for the radix of a system of notation, because it permits of only one bisection. The half of it is five, an odd number. It also is incapable of any other division. On account of these defects the system is ill adapted to the operations of the shop

and market. Although our calculations are universally made in the decimal system, none of our tables of weights and measures are decimal in any one of their subdivisions. In all departments of trade the current prices have been derived from a process of successive halvings. The shopman reckons by halves, quarters, eighths, sixteenths, and thirty-seconds, and not by fifths or tenths. The yardstick is divided in its practical use into halves, quarters, eighths, etc., by successive bisections. Even the sixteenth of a unit is more commonly used in trade than the tenth. In the stock-exchange, shares change in price by eighths of a dollar, and not by tenths. Even with our decimal system of money, we require coins for half and quarter of a dollar for practical use in trading. Almost the entire price-list of our stores advances and recedes by these fractions of a unit formed by successive bisections.

The attempt by the French to compel the use of the decimal system shows the difficulty of such an undertaking. Popular necessities compelled the introduction of binal divisions. The prices of their money and stock markets are still frequently quoted in quarters and eighths. The attempt to divide time decimally was a failure. After trying to give to their decimal metrology a universal application, they have been compelled to modify it in many of their weights and measures. From the inherent defects of a ten scale, all attempts to introduce an international decimal system of weights and measures have met with strong opposition.

The decimal system, then, appears to be ill adapted both to arithmetical calculation and to the practical needs of trade. Since the principle of the Hindoo notation is one of universal applicability, its merits do not arise from the number which happens to be used as its radix. One number, however, may be better for that purpose than another; and attempts have been made to supply the place of ten with numbers claimed to be more suitable. New systems have been elaborated and offered as substitutes for the one now in use. There is probably no one, except perhaps the authors of these new systems, who supposes that any of these, however theoretically perfect, will ever supersede our common decimal system. Yet these new systems of notation are not without a theoretical interest, for some of them are certainly better than the system which we are compelled to use. A brief statement of some of these curious systems will enable the reader to understand the advantages and disadvantages of our own.

The first and most noted is the binary system, first brought to the notice of Europeans by Leibnitz. He esteemed it so highly that he zealously urged its adoption. He claimed that its superiority to the decimal system was so great that time would be saved by reducing the decimal expressions of a problem to a binary form, performing the calculation, and then restoring the answer to the decimal notation. A short description of the system will show the peculiarities upon which this claim was founded: In the Hindoo notation the number of signifi-

cant digits is always one less than the value of the radix. In the decimal scale there are nine digits; in the binary, there would be only one—the figure 1. The radix, whatever it be, has no separate symbol, but is represented by 10. In the binary scale, since two is the radix, two would be so written. The square of the radix is represented by the symbols 100. In the binary these would, therefore, stand for four, while eight, which is the cube of the radix, would be denoted by 1000. The first ten numbers, counting from one, would be: 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010.

In this system, then, the only digit employed is 1. The 0 plays the same important part in it as in the decimal system. It multiplies the figure that immediately precedes it by the value of the radix. The symbol 40, in our denary scale, represents ten times four; in the octenary it would denote eight times four, and in the quinary five times four. These two symbols, 1 and 0, then, are the only ones that enter into calculations. It is evident that thought in arithmetical work is almost superseded, and that all numerical operations are reduced to the manual labor of writing. As the scale has only one digit, it would require more figures to represent a number than other scales require. The present year 1878, which is expressed in our scale by four figures, would require eleven in the binary scale. It would be written—10101010110. And, generally, the binary scale would call for about three and a half times as many figures as the denary. This fact would occasion increased expenditure of time and manual labor in calculations. It is, however, claimed by those who favor the system, that, since only two symbols are used, and since almost all mental labor is saved, it would, probably, in most calculations, afford a real economy of labor. But the great number of figures required would unquestionably make the use of this system a tedious process. It would no doubt be a favorite with children, since it has no tables of addition or multiplication; for all of its processes of addition are simple counting, since only the figure 1 is ever added, and there is no mental multiplication at all. Mathematical thought, therefore, is almost entirely dispensed with. This simplicity, it is claimed, gives the system a great merit on the score of accuracy.[1]

A system of notation with sixteen as a radix has also been proposed. It was invented by a well-known civil engineer, who gave to it the name

[1] The following illustration of a simple problem in multiplication will furnish to those who are curious in numerical matters an opportunity to compare the two systems:

Decimal.		Binary.
87	=	1010111
29	=	11101
783		1010111
174		1010111
		1010111
		1010111
2523	=	100111011011

of the Tonal System. He published an account of it about twenty years ago. It was carefully elaborated in all its parts, and a new system of weights and measures proposed to conform with it. New methods of dividing time, the sphere, the barometer and thermometer, were also proposed. A description, however, of so much of the system as relates to the notation is all that is required for our present purpose. The tonal system requires fifteen digits in addition to zero. Six new symbols were accordingly invented to represent the numbers, from ten to fifteen inclusive. New names were given to all the digits, in order to avoid confusion in using the new system. The reader may find it difficult to shift the symbols from their ordinary values to tonal ones; but, if it be borne in mind that **11** represents not ten and one but sixteen and one, **22** twice sixteen and two, **100** the square of sixteen, and that a similar change of value obtains with all the figures, the difficulty will disappear. The tonal figures below are printed in heavier type than the corresponding decimal ones, but the six new symbols are omitted.

The names and figures in this curious notation are as follows:

1	2	3	4	5	6	7
an	de	ti	go	su	by	ra
8	9	(10)	(11)	(12)	(13)	(14)
me	ni	ko	hu	vy	la	po
(15)	10	11	12	20	21	30
fy	ton	tonan	tonde	deton	detonan	titon
40	50	100	101	102	120	135
goton	suton	san	sanan	sande	sandeton	santitonsu

200	1000	10000	100000	1000000
desan	mill	bong	tonbong	sanbong

The new name "ton" given to **10** furnishes the system with its name of tonal. 0 was called "noll." The names of the figures above **10** were formed by simple combinations of the names of the digits. The present year, 1878, would be represented by **756** in this system, and be called *rasan suton by*. A lady 35 years old would be only **23** were the tonal system in use, and the grave author of the scheme called attention to this fact in an ingenious endeavor to make the better half of mankind warm advocates of the tonal counting.

However strange and fanciful this system may seem, its theoretical advantages are many and valuable. Its radix is susceptible of indefinite bisections, and is also a square and a fourth power. The vulgar fractions in common use, which require from four to seven places of decimals, would occupy only one or two when written in the tonal scale, as the following table will show:

	Denary.	Tonal.
$\frac{1}{2}$	.5	.8
$\frac{1}{4}$	.25	.4
$\frac{1}{8}$	.125	.2
$\frac{1}{16}$	.0625	.1
$\frac{1}{32}$	.03125	.08
$\frac{1}{64}$	.015625	.04
$\frac{1}{128}$	.0078125	.02
$\frac{1}{256}$	.00390625	.01

The disadvantages also of this scale are many. It requires a multiplication-table for all numbers from one to sixteen. The mental labor of calculating would, therefore, be increased. The number of symbols required would not be quite so large, but the advantage from this source would be slight. It may be noted, in passing, that in the Hindoo notation, the smaller the radix the greater is the number of symbols required to express any number, but the easier the mental work of calculating. The binary scale, which has the smallest possible radix, is an extreme example under this rule. For instance, the lady who would be called 23 under the tonal system would have to confess to no less than 100011 summers were she living among people who counted with a binary scale! On the other hand, the larger the radix the less the number of symbols required, but the greater the difficulty of computation. Thus the tonal system expresses numbers more compendiously than the decimal, but the difficulty of its many tables would make the use of it a continual and severe strain upon the mind.

Its author proposed also a tonal unit of linear, superficial, and cubical measurement, a tonal watch, a tonal compass, tonal wet and dry measures, a tonal currency for the world, a tonal division of time, tonal thermometers and barometers, and tonal postage-stamps. There is not opportunity in this paper to describe these schemes.

But other numbers might be used as radices, though most of them will be found to be ill adapted to the purpose. The number three would furnish a system which would possess no merits whatever. Its scale would present only two digits, and the first ten numbers would be 1, 2, 10, 11, 12, 20, 21, 22, 100, 101. But three is an odd number, and the first bisection would result in an endless fraction. The same is true of all systems in which odd numbers form the radix.

The number four, however, would furnish a practicable scale. It is a square, and can be bisected indefinitely without producing an odd number except at unity. The notation would be simple, and the tables of combinations easy to learn. Theoretically, the scale would be an excellent one, but calculations in it would require much manual labor, and consequently be more tedious than similar computations in our system. There would be three digits and the first ten numbers would be 1, 2, 3, 10, 11, 12, 13, 20, 21, 22.

The five scale, which is in use to a very limited extent among savage

tribes, does not furnish a good system of notation, because five is an odd number. The first ten numbers would be 1, 2, 3, 4, 10, 11, 12, 13, 14, 20.

The six scale is theoretically superior in some respects to the decimal, because its radix can be divided by three, but it is objectionable for the same reason as the decimal. Its radix admits of only one bisection. Its notation would be somewhat simpler than that now in use, but more places of figures would be required. Its first ten numbers would be 1, 2, 3, 4, 5, 10, 11, 12, 13, 14.

Of the seven, nine, and eleven scales, it needs only to be said that they present no merits, since the numbers upon which they are founded are odd numbers.

None of the scales to which we have briefly referred have been advocated as practicable systems, but the duodenary or twelve scale has many striking advantages, and is used to some extent for certain classes of calculation. Its radix is divisible by two, three, four, and six. It can be bisected twice. The system has not only been the favorite with many who have theorized upon the subject, but it has been used to a great extent by different nations in the practical affairs of life. The Scandinavian nations have a preference for this scale. Traces of its use appear in our words *dozen*, *gross*, and *great gross*. It also appears in quite a number of the primary divisions in our weights and measures. Its use is quite common among mathematicians in long arithmetical computations. The additional mental labor required to compute in this scale is not very great, while the manual labor is somewhat less than in using the decimal system. The scale has always been a favorite one with those who object to the decimal notation.

The sexagenary system, founded upon the number sixty, deserves a passing mention on account of its historical interest. It was used for a long time by the Greeks in astronomical and other calculations. Our subdivisions of time and the circle are made with reference to it; but for practical operations it is very laborious and complicated.

The octonary system, founded upon the number eight, most completely presents the qualities which are desired in a system of notation. Eight is without doubt theoretically the best number of all to be used. It is a cube, and admits of indefinite subdivisions by halving. The system appears to have all the merits of the sixteen scale, while it avoids the disadvantages of a large radix. It is much easier to use than the decimal scale. It requires only seven digits. The figures 8 and 9 do not appear, and its tables of addition and multiplication are much simpler than those now in use.[1] The danger of error in computations is

[1] The following multiplication-table, given by the author of an octonary scale, will show how simple must be the mental work of calculating in that system:

1	2	3	4	5	6	7
2	4	.....	.....	.....	.....	.....
3	6	11	.....	.....	.....	.....
4	10	14	20	.....	.....	.....
5	12	17	24	31	.....	.....
6	14	22	30	36	44	.....
7	16	25	34	43	52	61

correspondingly lessened. The mental work in using it would not probably be more than half that called for by our notation, while the number of places of figures required would be only slightly greater. The year 1878 would also be expressed by four figures, 3536, in the eight scale. Its fractions would be much simpler than those of the decimal system. They would differ very little from those of the sixteen scale.

The merits of the octonary scale have long attracted the attention of those interested in the subject of numerical notation. Charles XII. of Sweden seriously proposed introducing it in his kingdom. He commissioned Swedenborg to prepare the necessary details of a plan for establishing it. It is said that a complete system was elaborated, but the attempt to introduce it was prevented by the death of the king. No record of the system has been preserved.

But a complete octonary system has been elaborated, and a description of it was read by its author before one of our scientific associations about twenty years ago. In many respects, the details of it resemble those of the tonal system, which, in point of time, it preceded. New names were supplied for the digits as follows:

1	2	3	4	5	6	7	10	11	12
un	du	the	fo	pa	se	ki	unty	unty un	unty du

20	30	31	50	100	200	1000
duty	thety	thety un	paty	under	duder	untyder

10000	100000
unsen	untysen

The names of the larger numbers were made by compounding those of the smaller. Thus the present year, 3536, would be called *thetyder pader thety se.*

The octonary, like the tonal and quaternary scales, is without doubt admirably adapted to a natural system of weights and measures, and it is not without interest from a theoretical point of view. The disadvantages of the decimal system are clearly great, but the projects of those who expect to subvert it, with its immense store of arithmetical tables and formulas, are of course chimerical in the last degree. The author of the octonary system, just described, declared that the change involved no real difficulty, and that the national Government had only to will it, in order to bring the octonary scale into general use in one or two generations. But although the introduction of this or any other numerical scale in the place of the decimal is a dream without any probability of fulfillment, there can be no question that, theoretically, the octonary system of notation would be a vast improvement upon the one now in use, the basis of which was ignorantly bequeathed to us by our savage and barbarous ancestors.

MAN AND HIS STRUCTURAL AFFINITIES.[1]

By A. R. GROTE, A. M.

AN average coroner's jury might sit on the skeleton of an anthropoid ape and return a verdict that the deceased came to his death at the hands of parties unknown, with the sublime consciousness of having performed their duty and earned their fees. The suspicions of the more intelligent jurymen might easily be allayed by the common conception of what the word "monstrosity" will cover, and the similarity is indeed so great that I see no reason why the verdict should not be unanimous.

The gorilla has no more tail than a professor, while the knowledge that monkeys have tails, and the idea that these external appendages are a badge of general monkeyhood, are deeply rooted in the popular mind. But the apes are as tailless as man is, and no more so. I might say even less so, for the gorilla seems to have one caudal vertebra less than man; but we must give more weight to the head than the tail in matters of classification. In this world heads win throughout the game of life. Certainly, the bones of a gorilla, for instance, may be readily distinguished from those of a man, but certain bones in woman differ also slightly from the corresponding ones in man, and it is a recorded fact that juries have in this way mistaken the sex of the human subject of their deliberations. In England, in 1839, a double jury sat on the skeleton of a woman accidentally found, and upon which a man had been arrested for the supposed murder of his brother, for whose remains the bones had been mistaken. Their real nature fortunately transpired before a verdict was rendered. It is evident, however, that the bones of extinct animals have been mistaken for human remains, and so have inspired accounts of prehistoric giants; while it is certain that the bones of fossil mammalia have been revered as relics in Europe during the middle ages, and even up to the time of Cuvier. The correct determination of bones is, indeed, a more difficult matter than may be supposed from the readiness with which naturalists sometimes deal with the subject. A great deal depends on the state of preservation of the bone; and, again, what particular bone it is. Certain single bones, as the tooth, or one of the bones of the feet or hands, are much more decisive in their character than the ribs or vertebræ. The structure of the teeth shows a relation to the character and consistency of the food, and there is no doubt that, so long as the lion has his present dentition, and while his appetite remains, he will always lie down with the lamb—inside of him. In land-animals the bones of the limbs have more play in their sockets than in air or water animals, because flexibility is necessary to

[1] From a lecture delivered before the Buffalo Society of Natural Sciences, March 9, 1878.

speed over the ground or trees, but it is an objection where the limbs are to be used as paddles against the air or water. In fact, the more we know of the skeleton and the environment of the animal, the more we see that its variations throughout the animal kingdom are the combined results of the movements of the organism itself and the opposition of the medium in which it moves. Where the actions of the animal are slow, it is found that the bones of the limbs are more rigid and often joined, as shown in the case of the sloth by Prof. Cope. The head and the ends of the limbs, being in constant use against the vital conditions of the environment, are the soonest modified. The bones are formed by the muscles, and the muscles are developed through the movement of the animal. We may all have noticed that, when the skin is stripped off, and the extremities of the backbone, the head and tail, are cut off, together with the feet, the carcass of a cat looks much like that of a rabbit in the same condition.

Those who have not investigated such an instance of similarity, yet know that in a butcher's shop there is a superficial sameness in the appearance of meat which it is the business of a good marketer to see through; while a good many of us, who are unaccustomed to provide, would no doubt be not a little puzzled to distinguish the body of a calf from that of a sheep as it hangs in the stalls. The same thing holds good with the bodies of birds and other animals: a duck is identified most quickly by the webbed feet and flattened bill. Thus it is a matter, perhaps, of general knowledge that an animal is difficult to recognize when the head and extremities of the limbs are missing, and we see now the reason that it is so. We may go even further than this and account for the mistakes of antiquity on the same principle. It is not credible that the head or feet of a mammoth could have been mistaken for those of a man, nor were they as a fact; but a thigh-bone, or rib, offered less difficulty by reason of the greater resemblance. Hence we find that these mistakes have been made with some excuse for their commission. The difference existing between these fossils and the corresponding bone in man was so small as to escape the notice of the anatomists of antiquity. The general resemblance between the skeletons of all vertebrate animals was not then fully appreciated. People distinguished the animals in old times from man by their heads, feet, and fur, to say nothing of their tails; and, when they found an isolated internal bone, they may readily be forgiven for having wrongly referred it.

Again, the bones being produced through the muscles, and these through the nutrition of the animal, there is always a proportion between the skeleton and the stomach and soft parts of the body. The skeleton is a very good index of the comparative bulk of the animal, and this fact assists us when we attempt restorations of extinct species.

From the herd of monkeys found in the Oriental and Ethiopian regions of the Old World, the apes are readily distinguished by certain structural characters. The body is that of a human being, except that

the arms are proportionally longer, and the legs shorter, than in the average man. The face is very human from the structure and position of the eyes and ears. A tail, external to the rump, is entirely wanting. The body is covered with sparse and soft hair, except the face, toes, palms, and soles, which are bare. The species which has been written about the most, and about which, strange to say, we know the least, is the gorilla (*Gorilla Savagei*). Whether this ape was the species called by this name two thousand years ago by Hanno is doubtful and of no importance.

Wilson and Savage, two American missionaries, seem to have been the first, in 1846 and 1847, to bring us certain information of this comparatively near relative of ours. I do not think that we are grateful for the discovery. Generally speaking, we could have dispensed with this satire upon ourselves, although we have no responsibility in the case. At any rate, we can appreciate one value of missionary labor. American missionaries, by their intelligence and perseverance, have given us invaluable information from time to time concerning countries difficult of access, and their strange inhabitants.

FIG. 1.—HEAD OF YOUNG MALE GORILLA FROM HAMBURG MUSEUM. (From a photograph of alcoholic specimen.)

Since this discovery of the gorilla, the animal has been written about by several travelers. The accounts of personal encounter furnishedby Du Chaillu are now known to be largely fanciful; and Win-

wood Reade, a most reliable traveler, doubts if an adult has ever yet been seen alive in its native haunts by a white man. The specimens sent alive to Europe, and which have been claimed to be gorillas, have almost always turned out to be chimpanzees in various stages of growth. But the skulls and skins sent by Dr. Savage have been followed up by complete skeletons and preparations sent by other travelers, and naturalists have been able thus to study the appearance and structure of the most formidable of the man-apes, which is credibly stated to inhabit Central Africa from Sierra Leone in the north to Loango in the south. Living in the dense forests of that region and avoiding the presence of man, it is only with difficulty they are to be met with, and, from the inefficiency of negro courage and weapons they are rarely killed. We have thus no authentic portrait of the live adult gorilla, but we give here (Fig. 1) a picture of the head of a young male gorilla preserved in spirits in the collection of the Society of Natural Sciences of Hamburg.

In comparing the skeleton of the adult gorilla with that of man, we find that the vertebral column offers slight and unimportant differences. The number of ribs is thirteen; while in man it is usually twelve, but occasionally also thirteen are found. The curve of the back is slightly different because the erect position is not always maintained, and to this circumstance I would also attribute the difference in the shape of the pelvis. In man the viscera have to be supported during his usually erect position, and the bones of the pelvic girdle are larger, giving space for the attachment of the larger muscles of the spine and thighs, which render the attitude possible without inconvenient fatigue. But it is a fact that in a child, before it learns to walk, the pelvis is as contracted as in the apes. In its efforts to walk the girdle is opened out, the sutures being flexible during childhood. When we come to the skull of the gorilla, we find a great difference in the relative proportion of the different parts. The bones of the face are large and the jaws project. There is a variation in the different races of man in this respect, as an examination of the skulls of different races shows. The relative large size of the jaws and lower parts of the face we see in the negro races especially, as compared with our own, and to this type we give the name *prognathic*.

FIG. 2.—SKELETON OF GORILLA, AND MALE (*a*) AND FEMALE (*b*) SKULLS.

The man-apes show an excessive development of this type. At first sight this large development of the lower face and jaws might distinguish the apes from man with great clearness, but its importance

seems diminished when we compare the man-apes with the baboons and lower, tailed monkeys in this respect. The cranium of the gorilla is also very small in proportion to that of man. The contents of the smallest skull of man is given at sixty-two cubic inches; that of an adult gorilla is given at thirty-four cubic inches. But this difference loses much of its value when we see the amount of variation in men of the skull measurements. Thus the largest human skull shows a capacity of 114 cubic inches, being about twice the size of the smallest adult human skull.

Now, the difference thus shown in man of fifty-two cubic inches between the capacity of the largest and smallest skulls is greater than that between the smallest human skull and that of the gorilla, which is only twenty-seven inches. These figures will probably be still further modified so soon as we get accurate measurements of the skulls of certain African and Indian hill tribes more recently discovered. Indeed, it is already stated that twelve cubic inches of cranial capacity will cover the difference between the smallest human and the largest simian skull yet known. Again here, as with the prognathic characters, the importance of the difference in cranial size is diminished by the fact of its variation among the apes and monkeys, which latter are found to fall as much below the apes in cranial capacity as the apes do as compared with man. The skull of the gorilla exhibits considerable variation in the specimens which have been yet examimed. The males seem to have a prominent bony ridge on the crown of the skull, but this development of the bone stands in proportion to the muscles of the jaws which reach on each side up to the crest which they deposit. Where the jaws are weaker, as in the female, the crest is undeveloped, the muscles do not reach up so far and they deposit smaller ridges on the side of the skull. These crests are, however, wanting in the orang-outang, a lower kind of man-ape than the gorilla, where they are replaced by two bony ridges, a couple of inches apart, as we learn from Mr. Wallace's interesting writings. But the variation among the skulls of the gorilla yet examined is so great in the proportion of the different parts of the face, that it is evident there is a greater amount of individual peculiarity in this than in any other animal except man. This point is worthy of a much more extended examination than it is now possible to give to it. It is sufficient to state that these differences seem to have prompted Dr. Wyman and Du Chaillu to suspect species where in fact we find only one kind of gorilla as more specimens come to hand and supply the intermediary links. With regard to the permanent teeth of the gorilla they are thirty-two in number, just as in man. The principal difference is that the canine teeth, at least in the adult males, are longer than in man, and project. The jaws being more powerful and more constantly in use, the teeth are stronger and proportionally stouter than in man. And where we find any difference, such as is offered by the large canines, and the break in the lower series to admit of the play of

these fangs, we find, just as we did before, that there is a greater difference here between the man-apes and the lower monkeys than between the man-apes and man. The canines are either much more developed or there is a change in the total number of teeth indicative of a greater departure from the human type of dentition.

You will remember that I called attention to the fact that throughout the animal kingdom we were to find the greatest changes in the structure of the extremities of the limbs, because these were brought

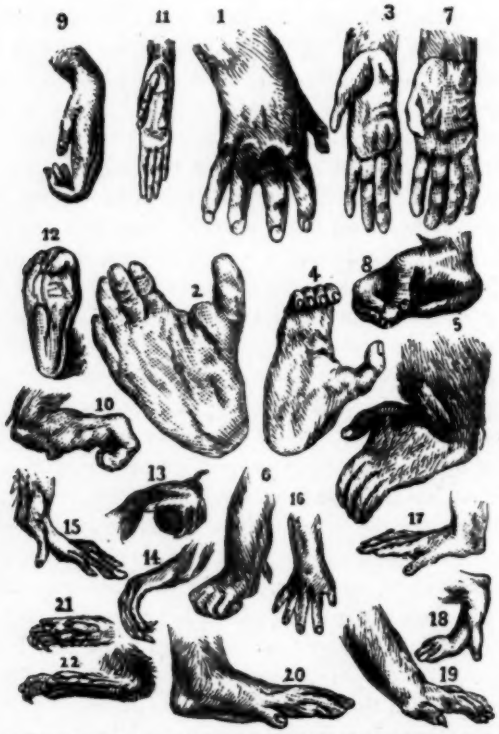

FIG. 3.—HANDS AND FEET OF APES AND MONKEYS: 1, 2, Gorilla; 3-6, Tschego; 7, 8, Chimpanzee; 9, 10, Orang-outang; 11—13, Gibbon; 14, 15, Colobus; 16-18, Malbrook; 19, 20, Baboon; 21, 22, Silk Monkey. (After Brehm.)

into constant use against the immediate surroundings of the animal. In truth, the greatest differences between the gorilla and man are found in the feet. The hands are not very unlike a man's; every bone and muscle is here again in its place; the thumb is a little shorter and the whole hand heavier. The muscles of the arm are more powerful and the hand is used for coarser work than man's, but after all not for work very different in kind. With them the gorilla builds a nest to sleep in, breaks off boughs, handles its food, and also attacks its enemy, holding him fast so that it can bite him. We do all these things with our hands; and there is a legal term, *mayhem*, to denote the crime of mutilation

with the teeth, which is not uncommon among brutal men of some countries considered civilized. But the foot seems at first very different from a man's, although here again every bone and the determining muscle (*peroneus longus*) of the foot of man are present. The foot is set more obliquely on the leg and the big-toe is farther from the rest, proportionally shorter and weaker, and, above all, more flexible. Certainly these important differences are connected with its mode of life, which is more arboreal than that of man.

With its foot the gorilla can steady itself in climbing and hold fast to objects from which the rigid foot of man would slide away. Still our feet are not wholly unfit for grasping, and you may have noticed barefooted boys cutting up "monkey-shines" on trees with entire safety to themselves, though not to the complete satisfaction of their parents. The female gorilla seems to consider her young one safe when he is up the tree; but the anxious human mother does not feel easy until the child is on the ground again. Circumstances thus alter cases throughout the range of experience. Again, we are familiar with the fact that men who have lost their arms often learn to write and perform other actions with their feet. But, notwithstanding these important differences between the feet of the gorilla and our own, there is again the greater difference to be considered between the hands and feet of the lower monkeys and those of the gorilla. The thumb ceases to be opposable in the American monkeys, and is again reduced to a mere rudiment covered by the skin in the spider-monkey. Indeed, we may say that, looking through the succession of simian forms, from below up, there is a constant increase of the characters which prepare us for man. And the gorilla exhibits these in their fullest development. From the gorilla it is indeed easy to predicate man—much easier than to suppose the gorilla from the lowest monkeys.

Another interesting man-ape is the chimpanzee (*Chimpanza niger*). Many living specimens have been brought to Europe and lately to New York from Africa, where it inhabits the same territory as the gorilla. It is a smaller species than the gorilla, the head proportionately larger and less prognathic, the arm shorter. The foot is more hand-like, and there is a slight difference in the dentition. In running, the chimpanzee goes on all-fours, but in walking or carrying anything the position it assumes is nearly erect. In captivity the chimpanzee has developed most amiable qualities. It has been taught to sit at table, and even to conform to what we esteem good manners. It becomes passionately fond of its keeper, clinging to him, and refusing to be separated on any occasion. It is extremely kind to children, showing no trickish or malicious temper, even endeavoring to amuse them, and induce them to play. As long as there is light in the room the chimpanzee will sit up at night; as soon as the light is withdrawn it goes to sleep, lying stretched out with its hands under its head if the temperature is pleasant, but, if cold, cowering together like a human being under similar

circumstances. It is evident that much might be done with the chimpanzee to make him an agreeable companion to man. Fortunately, this hard fate may be spared to the chimpanzee, because he cannot support existence in the colder regions to which our race has become acclimated.

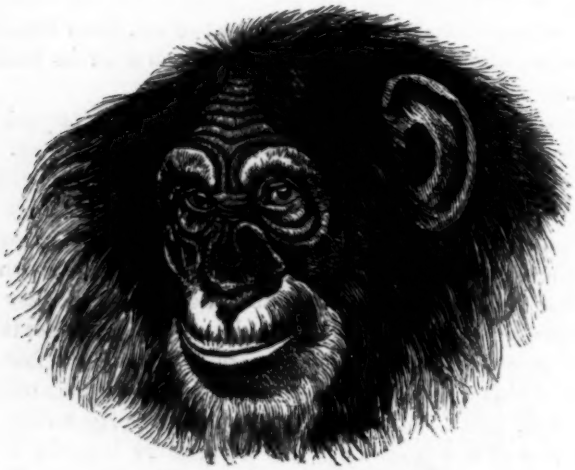

FIG. 4.—HEAD OF CHIMPANZEE.

The negroes do not seem to court his companionship. One notable feature in the chimpanzee remains to be stated, and that is his peculiar behavior to other animals. He is perfectly contemptuous in his treatment of our small, domestic animals, such as rabbits. He is frightened at large and fierce dogs, and exhibits an extreme terror at snakes and ugly reptiles. In this latter fact we recognize a mental state which is still shared by man, suggesting the probable origin of the serpent as an embodiment of the devil in the ideas of primitive man, and which still survives among us at the present day. Another species of man-ape is the tschego (*Anthropopithicus tschego*), which is only known from a single living female brought to Dresden from Loango. This species seems to be but little smaller than the *gorilla*, intermediate in size between this and the *chimpanzee*. In the proportion of its parts the most notable peculiarity seems to be that the legs are longer than in the other man-apes. The behavior of the specimen in confinement did not differ greatly from that already related of the chimpanzee.

The Asiatic man-apes differ from those of Africa by the proportionally longer arms, which reach down to the ankles. The orang-outang (*Simia satyrus*) inhabits most commonly the island of Borneo, and has recently been collected in considerable numbers by Mr. Alfred Wallace. It has only twelve pairs of ribs, as is usual with man. The body is broad at the hips, and joined to a pyramidal-shaped head by a short neck, which is still further concealed by heavy folds of the skin, which can be puffed out by the animal when angry. The eyes and ears are

small, but not unlike those of man. The nose is quite flat, the mouth is large and ugly, from the thick lips. The jaws are extremely powerful, and the canine teeth prominent. The breast is thinly haired, and the face, the fingers, palms, and soles, are naked. The back and top of the head are thickly haired, and on the side of the jaws the hair de-

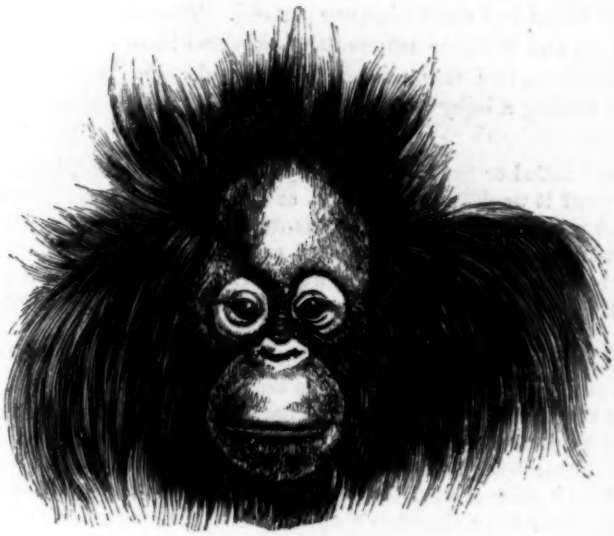

FIG. 5.—HEAD OF ORANG-OUTANG.

scends like a beard. In color the hair is a dark, rusty red, sometimes brownish on the back, the fringing hair of the face usually lighter than the rest. The color of the skin is bluish-gray. The old males may be distinguished by their longer beards, which are wanting in the young, and by a peculiar swelling of the cheek from the eyes to the ears, which makes their aspect more repulsive.

The orang-outang was certainly known to the ancients, and Pliny gives an account of this species which has been extensively copied. One peculiarity, only recently observed, is that the skull undergoes a greater change in shape than usual during growth. The heads of baby-orangs bear a close resemblance to those of infants; but afterward the lower portion of the face increases rapidly in size, and the aspect of the adult is more repulsive and animal-like than the chimpanzee. Wallace says they frequent swampy localities in Sumatra and Borneo, and visit the orchards of the Dyaks for the purpose of devouring the fruit. They build nests in the trees, of boughs, in which they sleep. They climb with great ease, and traverse the forest from tree to tree in a semi-erect position, assisted by their long arms, and are capable of progressing at the rate of eight or nine miles an hour without any appearance of hurry or fatigue, going as fast as a man on the ground beneath them can run.

The food of the orang-outang is strictly a vegetable one. It has the habit of not rising very early in the morning, waiting until the sun has dried the dews, and Nature has dressed herself for its appearance. Although the orang does not court danger, it does not seem afraid to fight if necessity obliges. Wallace narrates the combat between a Dyak and an orang, in which the native was terribly bitten and might have been killed had not assistance arrived. The orang was then killed by numbers, and Wallace rescued the skin and head to be added to his large collections, and taken later to England. Mr. Wallace also succeeded in finding a baby orang-outang, and gives his experience with it as follows:

"When handled or moved it was very quiet and contented, but when laid down by itself it would invariably cry; and for the first few nights was very restless and noisy. I fitted up a little box for a cradle, with a soft mat for it to lie upon, which was changed and washed every day; and I soon found it was necessary to wash the little orang as well. After I had done so a few times it came to like the operation, and as soon as it was dirty would begin crying, and not leave off till I took it out and carried it to the spout, when it immediately became quiet, although it would wince a little at the first rush of the cold water, and make ridiculously wry faces while the stream was running over its head. It enjoyed the wiping and rubbing dry amazingly; and when I brushed its hair seemed to be perfectly happy, lying quite still with its arms and legs stretched out, while I thoroughly brushed the long hair of its arms and legs. For the first few days it clung desperately with all four hands to whatever it could lay hold of, and I had to be careful to keep my beard out of its way, as its fingers clutched hold of hair more tenaciously than anything else, and it was impossible to free myself without assistance. . . . Finding it so fond of hair, I endeavored to make an artificial mother by wrapping up a piece of buffalo-skin into a bundle and suspending it about a foot from the floor. At first this seemed to suit it admirably, as it could sprawl its legs about and always find some hair. I was now in hopes that I had made the little orphan quite happy; and so it seemed for some time, till it began to remember its lost parent and try to suck. It would pull itself up close to the skin and try about everywhere for a likely place; but, as it only succeeded in getting mouthfuls of hair and wool, it would be greatly disgusted and scream violently, and after two or three attempts let go altogether."

This account is interesting, because it shows that in its actions the young orang-outang recalls what we are familiar with in infants; and again it illustrates the activity of the limbs at an early age and before they can be used intelligently. There can be no doubt that in this way we come to use our limbs at first, by a sort of blind groping in the uncertain light of infancy. We feel a sympathy for Mr. Wallace that his baby orang-outang never would do anything to reflect credit on its bringing-up, and finally died in an obstinate and childish manner. It was thought that it never entirely got over its separation from its family, but this may have been a fancy.

Another long-armed ape is the gibbon (*Hylobates lar*), which is smaller than the orang-outang and exceedingly intelligent. This spe-

cies readily assumes the erect position when not executing its incomparable gymnastic feats, swinging with its arms and leaping from one rope to another in the rooms fitted up for its dwelling in confinement. It walks with the knees bent and the long arms stretched out with the hands hanging down, reminding one of the position of a rope-walker. The gibbon is extremely neat and cleanly with its person, and is not distinguished by any peculiar odor, as are some of the other species of

FIG. 6.—HEAD OF GIBBON.

apes. As a prisoner the gibbon eats bread, milk, and fruit. Before drinking, it has been remarked that it tastes the fluid doubtfully with the tip of the tongue, which in the apes, as in man, is the most sensitive portion of that organ. Dr. Hermes says that the gibbon is an aristocrat among the man-apes and always on the best behavior.

I conclude this outline description of the man-apes with the statement that the duration of life among them is not accurately known, and probably varies with the different species. The gorilla and chimpanzee probably attain the average age of man.

The position of science with regard to man and the anthropoid apes is, that in no case can these latter be considered our progenitors or descendants. The physical and mental characteristics are too diverse to admit of such conclusions. The apes have evidently come down another line of descent, although the time when both the apes and man may have emerged from a common branch of the tree of animal life may not be so very long past. But, whenever the line of man and that of the anthropoid apes coincided, it is clear that now the tendency must be to diverge more and more. The resemblances between the apes and man,

however, cannot be overlooked by the thinking mind. They are so great that if we assumed the theory of degeneracy to be true, and so were willing to throw the whole animal kingdom backward on its tail instead of forward on its feet, we might consider them to be degenerate and "wild" men. And it is interesting to find that this is what they were formerly held to be. The early pictures of the orang and chimpanzee exemplify this notion by giving them perfectly human features and erect position, brutalized only by their hairy body. They were, in fact, assumed to be a very abandoned kind of man, and not a very elevated kind of monkey. It is thought by some tribes of men to this day that the apes could talk if they would, but they are afraid that if they do they will be made slaves of and obliged to work. From the naked white skin, through the yellow and red to the black and then to the black with hair, does, indeed, seem a gradual transition; and, if we concede the erect posture, the admission of the ape into the human family carries with it no little show of justice. It is not so long ago that we denied human rights, and both openly and impliedly consanguinity, to the negro, as to make it impossible that we should not come to regard the gorilla in a more affectionate light than we do at present. But, in point of fact, the different races of mankind represent a kinship remote in proportion to their structural differences; and most of us, perhaps, would be willing to admit at once the truth of this proposition. Science insists that it is true throughout the animal world, and expects that the time will come when it will be acknowledged, and our behavior improved by an increasing kindness on our part to our inferior and weaker fellow-inhabitants of the earth. The proof of the evolution of man we find first in the fact that for every bone and muscle or organ in man there is a corresponding one in the anthropoid apes. Having shown in this way that man is not separable from his physical characteristics, science enters into a comparison with regard to the difference in brain-power. The mass of the brain, as judged by the cubical contents of the cranium, we have seen, can be no certain criterion for the intelligence, but only of comparative value, because it was so variable in the apes and man. It is, however, a guide from a physiological point of view by which we can estimate an advance in thinking powers throughout the animal kingdom. It has been amply shown by Prof. Marsh that, as a whole, the proportion of the brain-case has increased through the succession of fossil vertebrate life from the time when coal was formed up to the present. And it can be shown that this proportion is greater in man to-day as compared with existing mammals. When we come to the structure of the mass of the brain, that of man offers no perceivable difference of importance from that of certain apes. The discussion on this point has been fully entered into by distinguished anatomists, and need not be detailed in this place. Alone, the weight offers a difference. The heaviest human brain known is given at 1,872 grammes, the lightest brain of a sane person 907 grammes, both these extremes

being furnished by women. The difference between the mass of the brain of man and that of the gorilla is proportionally, perhaps, the greatest that exists to separate the two. It has been considered by Huxley to approximate to twelve ounces. But the difference between the extremes of brain-weight in man, as exemplified in the figures here given, shows that we cannot consider intelligence to depend on the weight of the brain. All that we can say is, that a man with a large brain has capacity for the display of intelligence. It depends on his use of the senses, which are the feeders of the intellect, whether he displays high wisdom or not. It is quite possible that an ape may be more intelligent than a human being who has not properly supplied his brain with information. Human beings born dumb and blind are not born *ipso facto* intelligent, but are taught with great trouble and patience through the channels of the remaining senses. The facts known in regard to afflicted persons are amply sufficient to warrant the statement that the intelligence depends on the senses, and if these are interfered with, either in the structure of the organs, or by giving them a limited opportunity for activity, you have, as a result, less intelligence in the individual, be it man or ape, or other animal. We can show that the difference between man and apes is a *quantitative* and not a *qualitative* one.

A NEW PHOTOGRAPHIC PROCESS.[1]

So manifold are now the uses of photography that we need not dwell upon the importance of processes which allow of the employment of easily-handled apparatus, and which do away with cumbersome and fragile glass plates. Deyrolle's photographic process, described below, answers all the requirements of portability.

The idea of substituting sensitive paper for heavy, brittle plates of glass is not new, but all the processes hitherto offered labor under the serious disadvantage of necessitating a long exposure. Besides, the proofs are usually imperfect on account of the granulations which the paper leaves on the positive. M. Deyrolle's collodionized paper does not present these difficulties. It is covered with a special coating, insoluble in ether, alcohol, or water, and thus it undergoes all the operations of photography without change. This paper is collodionized and treated precisely as though it were glass. It is, in fact, quite equal to glass plate for the uses of photography, and in addition possesses the following advantages :

The layer of collodion is so firmly attached to the coating of the paper that it cannot be injured by contact with a hard object, nor even by slight friction. Besides, the picture can be developed by total im-

[1] Translated from *La Nature* by J. Fitzgerald, A. M.

mersion in the developing liquid, instead of pouring the latter on the collodion layer, as in the case of plates of glass, an operation that requires some dexterity and long practice.

This paper will retain all its sensibility for about two years, provided it be sheltered from light and moisture; it is not affected either by cold or heat. Hence it is destined to be of great use to travelers who explore remote regions.

After the light-impression has been made on the paper, it remains to develop the image. This operation presents no difficulty, success depending, so to say, only on the time of exposure. First, the paper is dipped in common water, care being taken to make the immersion complete. There it must remain for at least five minutes, or until the paper, which was beginning to curl, becomes perfectly flat. In the mean time the following solution is prepared in quantity only sufficient for the pictures to be developed at once, for oftentimes it decomposes in the course of a day or two:

Distilled water	1	litre.
Glacial acetic acid	20	grammes.
Citric acid	20	"
Pyrogallic acid	3	"

Into a basin with flat bottom, and of a size corresponding to that of the proof treated, is poured enough of the above solution to completely submerge the proof; a depth of three or four millimetres is amply sufficient. Into this is dipped the proof after taking it from the water and draining it, the collodionized side uppermost. After inclining the basin in every direction, so as to cause the liquid to pass several times over the proof, a portion of it is poured into a glass, and then we add to it a few drops of the following solution:

Distilled water	100	grammes.
Crystallized nitrate of silver	5	"

Stir well, so as to mix thoroughly. The whole is poured into the basin, which again is inclined as before. The image now appears; seven or eight minutes suffice to completely develop it, with the sky or the lighted parts of an intense black.

When the proof is sufficiently developed it is put in water, and then dipped in a solution of hyposulphate of soda, 40 per cent., to fix it; it is then freely washed in water in the usual way. It is now dried between leaves of silk-paper or blotting-paper.

Treated in this way the proof is perfectly secure: it is not affected by changes of temperature, and may be exposed either to damp or to drought without the least injury. To preserve it, we have only to place it in a book or in a portfolio, so that it may not be creased or rubbed on the collodionized side.

When we would take positive proofs, we detach from the paper the layer of collodion, thus getting the image on a thin transparent pellicle.

This is a very simple operation, consisting merely in adding to the collodion layer firm and transparent substances, till the *cliché* attains the proper consistence. To this end, we prepare a normal collodion of the following composition :

Gun-cotton	25 grammes.
Sulphuric ether	½ litre.
Alcohol of 40°	½ "

Lay the proof on a plate of glass, having first turned up the edges all round, so that the liquids to be poured upon it shall not overflow. On the collodion layer containing the image pour the normal collodion, beginning at one of the corners of the proof most remote from the operator. Then incline it slightly, so as to cause the liquid to flow ; and, after the entire surface has been covered, the excess of liquid, if any there be, is poured back into the bottle. Then the *cliché* is laid flat in a roomy box, or in any other place where it will be sheltered from dust,

and left for a few hours to dry. When fully dried, or when it is no longer sticky to the touch, we again, in the same way as before, pour over the layer of normal collodion a layer of caoutchouc dissolved in benzine. When this has become dry, we apply a second layer of normal collodion, then caoutchouc again, and, lastly, a final layer of normal collodion.

The *cliché* is now left to dry for twenty-four hours, and it is trimmed all around. Then, at one corner, the paper is separated by a finger-nail from the coating formed upon it. Having in this way loosened the coating at one corner, it may easily be stripped off altogether, with a little care, leaving the paper clean and white, as though it had never undergone any treatment. In this way is got a negative at least as transparent as though it were on glass; but it possesses the advantages of not being brittle, of not being damaged by rubbing, of occupying but little space, and, finally, of giving better proofs than can be got from *clichés* on glass.

To utilize this process, M. Deyrolle has constructed a strong but portable apparatus, made almost entirely of copper and iron, weighing not over 400 grammes for one producing proofs 0.13 metre by 0.18 metre, or 700 grammes for one producing proofs 0.24 metre by 0.18 metre (*see* figure on page 443).

The camera, which, when folded, is only four centimetres high, is held distended by two steel rods, which connect the frame of the object-glass with that for the slide. The support for the apparatus consists of three double legs with joints; these are fastened by thumb-screws to a triangular table. The stem supporting the camera is articulated with the centre of this table by means of a ball-and-socket joint, which allows the instrument to be turned in any required direction. The ball may be made fast at will by means of a steel spring. This new form of foot has the great advantage of being extremely light, and of allowing the camera to rest in any plane whatever.

We would add that, when this system is employed, the complete outfit of an explorer who wishes to take 300 negatives will not weigh over six kilogrammes, including the instrument, the *clichés*, and all the chemicals needed for developing the negatives.

VOLUNTARY MOTION.

By Professor PAYTON SPENCE, M. D.

"The primitive elements of the will have been stated to be—1. The spontaneity of movement; and, 2. The link between action and feeling, grounded on self-conservation. In the *maturing* or *growth* of the will, there is an extensive series of *acquisitions*, under the law of retentiveness or contiguity" (Bain, "Mental Science," p. 318).

"The elements of voluntary power being assumed as—1. Spontaneity; and, 2. Self-conservation, we have to exemplify the connection of these *into the matured will*, by a process of *education*" (Bain, "Mental Science," p. 325).

TO what extent we differ from the above propositions, and especially from those parts of them which we have italicized, will more fully appear in the following article.

To the superficial observer, a human being, during the interval between birth and adult life, seems to learn a great deal; but, if he did really learn all that he seems to learn, it would be marvelous in a degree wholly beyond the power of the human mind to conceive of, and far beyond the power of human language to express. Omitting, at present, that immense domain of the mind which is embraced under the terms sensation, emotion, and intellection, we will endeavor to make a comparative estimate as to how much we seem to learn, but do not learn, and how much we do really learn, in that limited department of the will which is covered by the term voluntary motion.

We will begin by endeavoring to ascertain how much a child would have to acquire in simply learning to pronounce the letter A, at will, supposing that none of the movements, or combinations of movements, which are made in the utterance of that one sound, are organic and inherited, but that they all have to be acquired or learned by practice and experience.

Between the states of the greatest and the least contraction of any muscle of the body, there are, of course, an infinite number of degrees of contraction. In order, however, that we may not seem to exaggerate the difficulties of the child's task, we will suppose that a muscle is susceptible of only three degrees of contraction, and that, therefore, three experiments, at most, would ultimate in the production of the sound of A, supposing it to depend upon the proper contraction of only one muscle. But how many muscles are engaged in the production of that one sound? A great many, namely, the muscles of the vocal chords, the muscles of the back part of the mouth, of the tongue, the cheeks, the lips, and the muscles that expand and contract the chest. We will largely understate their number, and suppose that there are only 20 involved in the pronunciation of A, each one of which, as we have already supposed, is susceptible of only 3 distinct degrees of contraction. Now, 2 muscles, each one of which is susceptible of 3 degrees of contraction, can be made to contract together in 9 different combinations, consisting of one degree of the contraction of each muscle to each combination; 3 muscles will give 27 possible combinations, 4 muscles 81 possible combinations, and so on, in a geometrical ratio of increase, up to the supposed 20 muscles, with which there would be 3,113,884,401 possible combinations of muscular contractions. Now, in all this wilderness of possibilities, there is but one combination which can produce the sound of the letter A, and that one the child must find, although, according to the supposition, he knows nothing about it, and has no organic tendencies in the direction toward it. He can find it only by experiment. Each possible combination must be successively tried and rejected, until he comes to the right one. Assuming that his chances of hitting upon the right combination are equal to his chances of missing it, the number of experiments which he would have to make,

before he would hit upon the right one, would be just one-half of 3,113,884,401, which is 1,556,942,200. Supposing, therefore, that the child makes 100 experiments in a minute, it would take him within a fraction of thirty years to attain the first successful utterance of the letter A.

But the child's task is not yet accomplished when he has succeeded in pronouncing the letter once. He must pronounce it again and again, before it is so completely within the reach of his will that he can pronounce it immediately, making automatically all the required muscular contractions of the combination the instant the volition calls for the letter. It is evident that, in the absence of all knowledge of those 20 muscles, and of all organic tendencies in the right direction (which could only be acquired by repeated successful experiments), it would be almost as difficult for the child to hit upon the right combination the second and the third time as the first; and, therefore, only after many successes would the required combination become automatic, and the utterance of the letter A really be so completely brought under the dominion of the will as to be classed among the voluntary movements. If, therefore, we again under-estimate the difficulties of the case, as we have done all along, and suppose that only 10 successful experiments would be necessary to accomplish the result—that is, to agglutinate into a unitary movement the required group or combination of muscular contractions, so that the group should be instantaneously and automatically adjusted the moment a volition is made for the letter A—we find that the child's lesson, the learning to pronounce a single letter at will, is a task which would require for its accomplishment 300 years of steady work, night and day, at the rate of 100 experiments every minute!

How insignificant, however, is the successful pronunciation at will of one letter, when we reflect that the child ultimately attains the voluntary control of, not merely one of the billions of possible combinations of 20 muscles, but that he attains the absolute voluntary command of all the 450 voluntary muscles of his body, individually and collectively, in all their possible combined, as well as isolated, contractions! In some of the combinations of muscular contractions which the child ultimately becomes capable of executing, nearly every one of the 450 voluntary muscles of the body participates; as, for example, in the throwing of a stone; and yet the wonderful combination is made and the movement executed with as much precision and promptness as the crooking of his finger. We have no hesitation in saying that, if all this had to be learned by the child, it would require a lifetime of many millions of years; and, as we know that the requisite knowledge or capacity is not a miraculous donation to the child, but must be the accumulated acquisitions of a slow process of experience of some kind, and at some time or other, we should be appalled by the magnitude of our own figures, did we not know that man is not the creature of to-day, but the child

of the ages, incubated in the primitive submarine protoplasm, born as the simple monad, creeping for æons of time as the blind-worm upon its belly, swimming for untold ages as the fish of the sea, flying as a bird in the air for hundreds of thousands of years, and, for centuries without number, roaming the earth as a mammal, and walking the globe erect as a man. But, all this time, immense and inconceivable as it is, would be too insignificant to enable one individual, unaided and alone, to learn (were it accomplished by learning) to execute all those infinite muscular contractions, and combinations of contractions, of which we have spoken; and we are only helped out of the difficulty by a knowledge of the fact that, in the evolution of the power of voluntary motion and of the will, in the animal kingdom, during all the immensity of the past ages, the organized experiences and acquisitions of all the millions of individuals of each species of animal life were, by the process of reproduction and the law of heredity, so completely interchanged and shuffled up with each other that the organized experiences and acquisitions of each individual became the organized experiences and acquisitions of the species, and the organized experiences and acquisitions of the species became the organized experiences and acquisitions of each individual.

We are now prepared to make an approximate estimate as to how much of our command over our voluntary muscles is acquired by education and experience, and how much is the result of the simple maturation of an inheritance, which evolution had prepared and stored up for us. If, as we have already shown, many millions of years would be required to enable one individual to acquire as perfect a control of all the voluntary muscles of the body as we know that each adult human being has, how much of that could be acquired by the individual himself after birth? Supposing him to reach the height of his muscular capabilities at thirty years, and that only 3,000,000 years, instead of many millions, are, as we have shown, necessary to enable him to obtain that complete mastery over his voluntary muscles which he actually possesses in adult life, then his own individual acquirements would bear the same ratio to his inherited acquirements that 30 bears to 3,000,000, or that 1 bears to 100,000. Therefore, he inherits 99,999 parts, and learns but 1—a quantity so small as to dwindle into almost nothingness in the comparison.

An apparent objection to our conclusions is met with in the fact that the child does not use his 450 muscles, at birth, with the same ease, precision, and freedom, that he does in after-years; but, from the helplessness of the babe, which can scarcely be said to make a single voluntary movement, there is a gradual advance in the variety and extent of his control over his voluntary muscles, until we may say that, by the time he reaches adult life, he is completely master of his voluntary muscular system. If, then, it is true that we acquire by education and experience nothing, or almost nothing, of that vast department

of mental acquisitions which is embraced under the term voluntary motion, yet it must be admitted that we seem to learn how to use our muscles, and it seems as if all our voluntary control over them were acquired by education and experience. It is but seeming, however; and, instead of our learning *how* to use our muscles, we simply learn that we *can* use them, in all the endless varieties of isolated and combined contractions of which they are capable. The *how* of their use is our vast organized inheritance; and it is this which gives even the child, as he matures, that sure, unerring tendency to the right movement to attain any desired end, and soon *teaches him* that he *can do what he wills to do*, thus obviating a resort to that infinitude of experiments which, as we have shown, would otherwise be absolutely necessary. It is the organized inheritance which takes the lead, and teaches the child that he can make the required voluntary movements, and not the child which teaches the organization how to make them. The newly-born babe is helpless and capable of making only a few instinctive or automatic movements, not for want of education and experience, but for want of organic *maturity;* and, hence, we see that some animals which are more matured at birth, or when hatched, than the human infant, walk, run, swim, or fly, as soon as they are born, or as soon as they escape from the egg; and the butterfly and those insects which emerge from the chrysalis *fully matured* need no experience or education whatever to enable them to command at will all their voluntary muscles; their organic maturity alone giving them at once full control over that department of their nature.

In the case of the child, it is impossible, either by observation or experiment, to separate the results of the maturation of the organization from the results of education and experience, for the obvious reason that the maturing of the child's nervous and muscular system proceeds, at a very rapid rate, simultaneous with its education and experience; and, therefore, were the point not already settled by the estimate which we have just made, it would be impossible to form even an approximate estimate as to how much of the child's progress is dependent upon his own acquisitions, and how much upon the ripening of an inherited organization. It is not possible, experimentally or otherwise, to isolate these two factors and their results from each other so as to ascertain, in that way, which factor is the largest and most important. The child's muscular education, the progress which he makes in his voluntary control over his muscles, and the maturing of his organization, all proceed simultaneously and inseparably together. Nevertheless, facts do occasionally crop out, here and there, confirmatory of the calculations already made, and the inferences drawn from them, if they needed confirmation. If our voluntary control over our muscles is not an educational acquirement, but is the result of the ripening of our organic inheritance, we would naturally expect an occasional exhibition of muscular agility, precision, and dexterity, and

of complicated grouping and combinations of many muscles, far beyond any educated capacity which the individual is known to have acquired. This expectation is frequently realized in individuals when under the dominion of exalted emotions, in insane persons, and in persons when in mesmeric, somnambulic, trance, and other abnormal conditions, who often perform feats of agility, dexterity, and wonderful freedom and precision in the combined contractions of a great many muscles of the body, equaling the nimbleness and mobility of the ballet-dancer, the sure-footedness of the rope-walker, and the consummate skill of the trained acrobat, although they had no special training calculated to qualify them for the performance of such feats. In fact, in their normal states, they did not believe themselves capable of performing such feats, because they had not yet learned that the feats, marvelous as they seemed to themselves and others, were already accomplished facts, packed away in their organizations, awaiting the magic word, the real "*open sesame*," to command them to come forth. The records are loaded with such unused facts, that are simply labeled "abnormal," and then abandoned. It will generally be found, however, that the abnormal, simply from the fact that it is abnormal—an outlaw to all that is now considered fixed and established in science—is the key to a higher law and a broader generalization. A few illustrations will suffice :

Dr. Rush relates the case of a young man named Wilkison, in whom the habit of stammering was suspended during his mental derangement, but returned as soon as he began to mend.[1] It is evident that, in stammering, the groupings of muscular contractions which produce articulate sounds are very different from those which produce the sounds without stammering. From some cause, not yet understood, there is in stammering an interference with the correct muscular groupings which, we claim, are organic and inherited, and a series of random, confused, and semi-spasmodic muscular movements become mixed up with the correct groupings. In this instance, the mixture had continued from childhood up to manhood, a period long enough surely to have agglutinated them indissolubly together, if practice, habit, or education, ever caused such agglutinations, as some believe. It is evident, therefore, that this man not only had not learned or acquired by education the correct use of his muscles of articulation, but had seemingly acquired an incorrect use of them ; yet, the moment he became insane, the impediment was removed, the habits of a lifetime vanished, and his organically inherited command over those muscles asserted itself, and enabled him to do what he had never done before, and what, unless the views which we have presented are correct, must be acquired after birth, and can only be acquired after birth by long-continued practice.

The following case is related by Dr. Abercrombie : A lady laboring under some disease of the nervous system, not disclosed by an autopsy,

[1] Rush, "Medical Inquiries and Observations on Diseases of the Mind," p. 254.

as she recovered, exhibited, among other things, the following remarkable powers:

"After lying for a considerable time quiet, she would in an instant throw her whole body into a kind of convulsive spring, by which she was thrown entirely out of bed; and in the same manner, while sitting or lying on the floor, she would throw herself into bed, or leap on the top of a wardrobe fully five feet high. During the whole of these symptoms her mind continued entire, and the only account she could give of her extravagance was, a secret impulse which she could not resist."[1]

This case cannot be disposed of by saying that the movements were convulsive, because it is evident that they were definitely combined and adjusted to the production of a well-defined result—the landing of the patient's body either upon the floor, the bed, or the wardrobe—so that a certain amount of mentality or volition accompanied the result; this she herself was aware of, and called it a "secret impulse." It is also evident that the movements were very complex, and required a special and peculiar coördination of a great many muscles; in fact, nearly every voluntary muscle of the body. The only conclusion at which we can arrive is, that the patient, in the abnormal state into which disease had thrown her, was able to draw upon an inheritance of muscular capacity to which she had matured, but which she had not been called upon to use before.

Dr. Abercrombie also relates the following case: A young lady, fifteen years of age, was subject to attacks of catalepsy, in consequence of a fall from a horse.

"On one occasion, she was playing from a book a piece of music which was new to her, and had played a part of it, when she was seized with a cataleptic attack. During the paroxysm she continued to play this part, and repeated it five or six times in the most correct manner; but, when she recovered from the attack, she could not play it without the book."[2]

In this case the young lady was able to execute, in the cataleptic state, what she apparently had not learned and could not execute when out of that state. From this and similar cases it would seem that much of our inherited voluntary command over our muscles is ordinarily disguised or marked, as it were—held in abeyance—how or why we know not, and we are enabled to get glimpses of it during those states of mental and organic spontaneity and mobility which, for want of a better name, we call abnormal, and which often seem temporarily to put the individual *en rapport* with the secret chambers of his own boundless wealth—the countless treasures of ages of accumulation.

The following case, taken from the *Globe-Democrat*, of St. Louis, Missouri, is as remarkable, perhaps, as any of a similar character on record:

[1] Abercrombie, "Diseasse of the Brain and Spinal Cord," p. 292.
[2] Ibid., pp. 293–295.

"James H. Prior, of St. Louis, has an adopted daughter, of thirteen years, who performs wonderful gymnastic feats in her sleep. Finding her room vacant one night, Mr. Prior began a search, which resulted in discovering her walking along a narrow iron railing which protected a gallery running the entire width of the house. When she reached the end of the railing she deliberately turned and walked back. This she performed with grace and apparent carelessness. In the mean time Mr. Prior, fearing that if he moved it would startle the girl, and she would fall to the paved yard below, remained quiet while she continued her perilous walk. In a few moments she seemed to be satisfied, and, carefully stepping to a chair, reached the floor, and glided slowly by Mr. Prior, down the hallway into her apartment and bed, where she was soon sleeping sweetly. At another time, Mr. and Mrs. Prior found the girl had crawled through the skylight, and was promenading the length of the roof-ridge. She was walking with her hands hanging listlessly by her side, and her head inclined forward as if she were looking immediately in front of her feet. The moon was shining brightly, and the white, lithe form of the sleeping girl could have been seen a block distant. There was a chimney half-way to the ridge, and sometimes she made *détours* to the right or to the left, going completely around the obstruction, regaining the ridge and traversing its entire length. Once she leaned on a chimney, and seemed absorbed in meditation. Each time she reached the end of the roof it appeared to be her deliberate purpose to walk off, but she always checked herself when within a foot of the edge, and, slowly turning, carefully retraced her steps. Twice she descended on the incline of the roof, each time returning to the ridge very rapidly, as if she had met with something that excited her fears. Several times she looked up, as if gazing at the stars or listening to some distant sounds. Suddenly, while at the point of the ridge, which she had first reached, she began to descend in the direction of the skylight, taking each step with great caution and making slow progress. When she had nearly reached the opening Mr. Prior quietly withdrew. In a moment Laura followed, proceeding at once to the garret-stairs, and disappearing down the dark passage. Mr. and Mrs. Prior followed, keeping behind her as close as possible, but, before they could reach her, she was in her own room, and composing herself in bed."

Whatever voluntary muscular movements we may make, therefore—be they ever so new and wonderful to ourselves or to others—we make because we can; because they are already accomplished facts packed up in our inherited organization. The truth of this proposition makes its converse also true, and the proposition itself receives additional confirmation from the truth of the converse, namely, whatever muscular movements are beyond our voluntary control are so because they are not accomplished facts in our inherited organization. Take, for example, the familiar, schoolboy, muscular puzzle, which seems to be a very simple movement, and very easy of execution; yet we doubt whether it has ever been really mastered, even after the most protracted efforts, so that it could be executed with the automatic ease and dexterity with which we execute our voluntary movements. It is easy enough to extend the forefinger of the right hand, and revolve it rapidly so as to describe a cylinder as it moves; it is also easy to do the same thing with the forefinger of the left hand; and it is equally easy

to revolve them both at once in the same direction; but the puzzle is to revolve them both at the same time, but in *opposite directions*, the points of the fingers facing each other. Much practice may enable one to execute it slowly, defectively, and awkwardly; never, however, with the same ease, freedom, and dexterity, with which we revolve either finger alone, or the two fingers together in the same direction. Again, it is not only difficult, but impossible, simply by a voluntary effort, or by any amount of practice, to roll one eye up and one down at the same time, or to turn both outward at the same time, beyond the parallelism of their axes. The muscular combination or coördination required in such movements is not organically possible, and no amount of education can make it so; otherwise, education would be a substitute for evolution and maturation.

The current ideas of the growth of voluntary motion and the will are based upon an ill-defined notion that the muscular and nervous systems were first developed, like a piece of complex machinery, and then the mind somehow came into *rapport* with it, or happened to be there, just at the right time, and commenced to learn how to work a certain part of it—for it is admitted that the rest can get along without the mind. But the truth is, the importance of the mind as a factor in the movements of the body is vastly overrated. It never really learns how to work even the limited portion of the organization which the current theories assign to it. When a child or even a man makes a certain voluntary movement for the first time, and practises it until he can execute it with ease and rapidity, has he learned how to do it? If so, he can tell how it is done. But, the fact is, he has learned nothing at all about the mechanism which he seems to handle so dexterously, and can give no account whatever as to how he does it—that is something which has staggered the most capable and profound students of voluntary motion and the will. Look at it. A child reaches out after a bright object and misses it. Does it know how or why it happened to miss it? It keeps reaching, fumbling, and trying, and now it grasps it. Does it know how or why? Does it know that now it opens an outlet or a valve of nervous discharge which then was closed; or, that it shuts one which it had left open; or, that it opens three instead of two or one; or, that it opens them one-half, one-third, or one-fourth, instead of full flood? Does it learn any of these things, and then treasure them up in the memory consciously or intentionally, so as to be able to do it again, next time, without balk or failure? The growth of a voluntary movement is an organic procedure, not such a mechanical process as that. That would, indeed, make the organization a machine for the mind to manipulate, instead of the mind being (as we think we can easily show) but *a symbolical representation in consciousness of the workings of certain parts of the organization—the brain.* Then, when we have mastered a voluntary movement, all that we have really learned is *that we can make it.*

But, again, a bright object is presented to a child. Its desire for it ultimates in a movement that misses it, and then in one that grasps it. In what respect do the mental accompaniments of the movement differ in the two cases? In nothing whatever. The mental phenomena which accompany both the failure and the success are a desire for the object and a volition for the movement. Next week or month, you hold the bright object before the child again, and he succeeds in grasping it every time; and still the mental accompaniments of the movement are the same—the same desire for the object, and the same volition for the movement—not for the wrong movement, even when the failure was made. Then, if the desire and the volition are precisely the same in both cases, why should one movement be a success and the other a failure? It is evident that the fact that the child has learned that he *can* make the movement does not contribute to the success, for the first success was made before he had learned that he could; and the knowledge that he *can* does not contribute to a future success, because it does not contribute in the least to a knowledge of *how* to do it. Then, where are we driven to? The mental accompaniments or phenomena do not (with a qualification which it is not important to explain here) contribute to the success of our voluntary movements. Therefore, we must look for the reason why one voluntary movement is a success and another a failure, in the phenomena of organization, and not in those of mind.

If the final conclusion above reached is true, there should be no difference, physiologically, between a voluntary and a reflex movement. And such we find to be the case. The essential physiological phenomena of a voluntary movement are, an impression upon a peripheral surface, conducted thence along certain nerves to a nervous centre which is thereby excited to a peculiar kind of molecular action, and that action generates what is called a nervous force, which is discharged through another set of nerves upon certain muscles, causing them to contract. The essential physiological phenomena of a reflex movement are precisely the same. The point of present interest in both cases is that peculiar molecular action of the nervous centres (which, as we have stated, is essentially the same in both cases) which generates the nervous force that is discharged upon the muscles, causing their contraction. Now, if there is no essential difference, physiologically, between a voluntary and a reflex movement, in what do they differ? Of course, the former is the latter with volition superadded, or the latter is the former with volition deducted. And what is volition? Volition is simply a peculiar molecular action of a nervous centre of motion reflected upon consciousness—translated into a state of consciousness—symbolized in consciousness. The mental part of the phenomena—the volition—being simply a state of consciousness—a consciousness of the molecular action—then, the molecular action is a condition precedent to that state of consciousness which is a symbolical representation of it. The molecular action, being precedent to the symbol of itself, can-

not be determined or controlled by that symbol—that state of consciousness—that mental part of the phenomena which we call volition. Therefore, if from a voluntary movement we strike out the only mental part—the volition—which, as we have seen, is not a factor, what is left is as purely organic, and hence as purely reflex or automatic, as the movements of a decapitated frog upon the application of an external irritant. Of the truth of this we may satisfy ourselves by simply looking at the nature of a voluntary movement from another point of view. Thus, I will to move my arm, and it moves. The only voluntary part of that very complex operation is the volition itself. I do not intentionally and knowingly direct the nervous discharge along one set of nerves rather than another, or upon one set of muscles rather than another; nor do I knowingly and intentionally cause one set to contract and another to relax, or one to contract much, and another little, and another less. All these things, which are so numerous and complicated in that one movement, and which constitute the whole of the mechanism, are purely automatic, being not in the least dependent upon the mental part—the volition—although wholly dependent upon that organic activity of which the volition is a symbol in consciousness. It is easy to understand, therefore, that if the molecular action which generates the nervous force that causes a reflex movement could be symbolized in consciousness, that symbol could not be called anything but a volition—a mandate for the movement. As many reflex movements are movements which were once voluntary, and have become reflex by a withdrawal of them from the sphere of consciousness, to relate them again to consciousness would be to make them again voluntary. While it is very easy to understand how a reflex movement might thus be converted into, or restored back to, a voluntary movement, it is an actual fact that by dislocating consciousness from its connections with voluntary movements we at once make them reflex or automatic, as is the case, for example, in many habitual or oft-repeated movements, such as the fingering of the keys of a piano when the music is known by heart. The following singular case is also in point: Many years ago, a medical gentleman related to me a case which came under his own observation, namely, that of a lawyer, who, without any other perceptible physical or mental disorder, would, in the course of ordinary conversation, let slip one or another legal term between words and in sentences with which it had no connection whatever. They seemed to utter themselves without any volition on his part, and in fact he did not know that one was coming until it was pronounced. The muscular movements in such cases are wholly automatic, which means wholly organic, without any associated mental phenomena.

From the foregoing considerations it is evident that a scientific solution of the problem of voluntary motion (and that of the will which is based upon it) requires a full and separate consideration and explanation of four distinct branches of the subject, namely:

1. The genesis of the power of voluntary motion, or its differentiation from some mental power which preceded it ; and how it was differentiated.

2. The evolution of the power of voluntary motion considered as an organic procedure in the entire animal kingdom, by which it was developed from its earliest genesis up to its highest capabilities in man, as the result of such changes in the faculty, from any cause whatever, as were transmissible and transmitted by inheritance.

3. The maturation of the power of voluntary motion considered as an organic procedure in the individual (man, for instance), by which it develops or ripens through the gradations of evolution independently of the operation of any external cause, such as education and experience.

4. The acquisitions of the power of voluntary motion, or whatever is added to the maturing or matured faculty, by which it is enabled to do with greater ease, freedom, force, or dexterity, what, without evolution and maturation, it could not do at all, and could never be educated to do.

In view of these obvious facts, were we to venture a criticism of Bain's celebrated treatise on the will, we should say that his method is defective, inasmuch as he has disregarded those natural and important divisions of the subject which we have pointed out, each of which requires a separate treatment. The careful reader will be able to discover not a little confusion in that treatise, and will be able to trace it to the fact that the distinguished author has treated as a unit things which are so dissimilar ; and especially is this true of his method of dealing with maturation and acquisitions, by which the reader is led to believe that acquisition is maturation, and maturation is acquisition.

MONERA, AND THE PROBLEM OF LIFE.

By EDMUND MONTGOMERY, M. D.

I.—INTRODUCTORY—THE PROBLEM IN GENERAL.

OF late years the hypothesis of the gradual and continuous evolution of the universe and its parts has become the growing conviction of almost all scientific minds. The main drift of the new philosophy, the central aim of scientific exertion, is to establish by means of exact investigation the reality and true order of this natural development of things. After much anxious guess-work in which the emotions have been profoundly implicated, we begin at last calmly and positively to desire to know how deeply our existence is interwoven with the sensible world everywhere surrounding us. We wish to know whether we are, body and mind, the veritable heirs and trustees of these stupen-

dous achievements of ever-toiling Nature; or whether we are merely passing strangers, endowed with a principle of life otherwise sustained, with an essence of being not vitally implicated in the general enchainment of temporal occurrences. On all sides we are fervently striving to gain assurance of, at least, this one leading position in our mysterious fate. To whatever sources of revelation seem available, there is put in every imaginable shape this decisive question: "Do we or do we not entirely belong to the actual state of things in which we at present find ourselves involved?"

This is evidently the real import of the momentous controversy now provoked anew, on deeper grounds than ever before, by the adoption of the evolution hypothesis on the part of Science. In all quarters of our globe, from every laboratory and study, where the investigation of any branch of Nature is methodically pursued, we hear the voice of Science proclaiming, with all but unanimous accord, one and the same truth, that through natural development, from lowest beginnings, has grown, step by step, all of which we can ever gain any knowledge. This is certainly a grave conclusion, coming as it does from the most cautious and reserved school of thinkers. If proved to be true it must, in course of time, necessarily subvert all former creeds, changing completely the groundwork of human faith, and prescribing to life new guiding principles. To mistake this inevitable issue of the grand contest entered upon by the students of Nature against the authority of their own mental inheritance would betray either short-sightedness or insincerity. Let none, then, remain in doubt that it is the serious intent of evolutionists so to unfold the system of Nature, the philosophy of synthesis, of organization, as to make it eventually the bearer on a strictly scientific foundation of all manner of truth. On all sides they are challenged to make good their assertions, and to show how we ourselves, with our exalted faculties, have come to be part and parcel of this same supposed onward flow of natural events.

The disciples of Science are accordingly everywhere at work to raise to the dignity of a consistent theory what is promiscuously held on the strength of much good evidence, though also in reliance upon the eventual verification of much vague foreshadowing: though it is incumbent upon us as evolutionists to prove our opinion, yet it must be admitted that at present we are far from having established a connected chain of evidence in support of it. We cannot deny that, when from the point of view of our present knowledge we attempt to survey the gradual ascent from lower to higher cosmical manifestations, we are abruptly checked at various critical points. The continuity of that surface, on which our understanding is wont to skim the depths of reality, presents sudden chasms. We experience one such sharp mental recoil when we endeavor smoothly to glide from the inorganic into the organic world. For, whatever may be asserted to the contrary, Science does not yet exactly comprehend the transition from lifelessness to life.

Nor can it account for, or even follow with any degree of precision, the stages of transformation leading from apparent uniformity of structure to diversity of organization. The origin of life, and the conditions which have gradually given rise to organization, are essential evolutional moments, as yet in the twilight of mere fanciful conjecture. Their penetration and elucidation would yield the data for the solution of what may be called the physical phase of the problem of life.

But, further on, in pursuance of evolutional continuity, we encounter a still deeper mystery, separating most profoundly the world of matter from the world of mind. We are all aware that this strange contrast of matter and thought, of the extended and the inextended, has ever constituted a fundamental dualism in human experience. Philosophy in every one of its aspects is mainly the result of an effort to imagine or to recognize the connection which necessarily must obtain between the ideal and the real. But there has been far too much imagining, and too little recognition, in the endeavor. So, till quite lately, in the history of human thought, but very slight advance was made in the solution of the central puzzle, concerning ideality and reality. Modern Science, disgusted at the waste of so much precious energy and earnestness, given up to the elaboration of mere whimsical and visionary interpretations, set out with the positive intention to evade in its investigations any contact with this constant stumbling-block of certitude. But the antagonistic powers of outwardness and inwardness are too intimately blended in Nature to admit of any such artificial severance, however skillfully attempted.

Scientists are becoming more and more conscious that, even in their least complicated suppositions and inquiries, both those elements of the actual world are always inextricably involved. Before the steadfast glance of Science, the eternal, adamantine atoms, questioned as to the essence of their subsistence and resistance, dissolve into unextended, immaterial centres of force. Before the steadfast glance of Science, the inscrutable forces, with their ideal sweep, traced to the immediate seat of their activity, resolve themselves into the discrete multiplicity and absolute impenetrability of adamantine atoms. Surely, if with witches "fair is foul and foul is fair," with us benighted mortals confusion seems to reign still more supreme, for, to our profoundest thinkers, matter is force and force is matter; motion somehow is sensation, and sensation somehow motion. And yet how can we aspire ever clearly to comprehend the fundamental identity of such disparate manifestations as matter and mind?

Naturalists are aware of and openly acknowledge this mysterious polarity of phenomena, this double subsistence—one in reality and at the same time also in ideality. To the former mode of existence they give the name of motion, the latter they call sensation—motion being the generalized fact of outwardness, of objectivity; sensation being the generalized fact of inwardness, of subjectivity.

But Science does not yet understand, nor does it pretend to understand, the enigma. Like all previous systems of knowledge, it fails to detect the actual concatenation, the necessary connection or continuous transition, by which these two seemingly heterogeneous experiences are bound together and unified in reality. It does not conceive how motion can possibly generate sensation, or indeed how motion and sensation can in any way be related to each other. Yet, to the vindication of the hypothesis of evolution, it is quite indispensable to establish either the essential identity of motion and sensation, or the gradual transformation of one of these modes of existence into the other. For how can evolution maintain its pretensions to universality, if the ideal world remains foreign to it—a mysteriously correlated entity, merely in close correspondence with the outer world, but having with it no genuine and intrinsic sameness of actuality?

The penetration and elucidation of this ancient dilemma of motion and sensation would furnish the data for the solution of what may be called the psychical phase of the problem of life.

But intermediate between these two extreme aspects of the problem —the one demanding the explanation of the origin of vitality and organization; the other the proof of the identity or direct phenomenal continuity of motion and sensation—there is disclosed by the requirements of the evolution hypothesis a third essential and very peculiar aspect of the same problem. As the experience of sensation, the state of so-called feeling is an exclusive attribute of vitality; it is evident that, granting the evolution hypothesis, feeling must make its appearance and take its rise at some definite moment in the course of organization. The demonstration of the specific conditions of organization, which constitute the starting-point of feeling or subjective experience, would furnish the initial data for the solution of what we may call the physico-psychical phase of the problem of life.

We have now gained some information regarding the ground which has to be accurately explored before the hypothesis of continuous development can be said to be adequately established. Having indicated the exact points at which our scientific appreciation meets with the most abrupt and startling breaks in the supposed continuity, we find ourselves in a favorable position to estimate what, above all, has to be accomplished before evolution can take the field as a consistent monistic system.

We have to show how life originates and how organization takes its rise; we have to demonstrate how in the course of organic development the state which we call feeling is established; and we have, finally, to prove that this feeling is in essence identical with that which is felt. How are we to set about this seemingly hopeless and endless task? Are we to rummage the vast stores of accumulated facts in search of the missing links? Assuredly, had they been forged and ready for the purpose, more competent and assiduous searchers would have discovered them long ago.

Are we, in our trial to establish the necessary connections, simply to draw upon our innate power of synthesis, again once more to stimulate the much-jaded faculty of mental constructiveness? Assuredly, if the material for the verification of any logical supposition had been extant, the master-minds, who have so admirably dealt with this great subject of synthetical continuity, would have left no material chasm unbridged. Are we to find what we are in need of by laying open to inspection the subtile intricacy of the sanctuary of life, by minutely investigating the intimate composition and working of the mysterious organ of centralization? Dazzled by the wonders of this marvelous fabric, the consummated fruit of the mighty tree of life, there is assuredly danger that we shall fail to catch any glimpses of its dark and lowly origin.

It is very natural, then, and appropriate, that, seeking a way out of our scientific perplexity, we should direct attention to the study of vitality in its least complicated forms, which manifest the properties of life, and at the same time do not confuse us with structural entanglements. For, wherever we find fixity of differentiated parts already established, there the difficulty begins. The organism gains the appearance of a mechanical contrivance, and we feel at once puzzled as to what is driving and what is driven in the living engine. We desire, then, if possible, to become acquainted with life before it has assumed any definite shape, before the manifoldness of its relations has acquired any degree of stability, or settled morphological expression.

The least complicated forms of life now known are perhaps motionless, non-nucleated corpuscles, which are observed to grow and to multiply by division. But vitality in these forms displays itself so torpidly, or at least so clandestinely, that microscopic investigation is incompetent to detect the nature of the changes that constitute their vital activity. Besides, these motionless corpuscles are probably all inclosed in a membranous envelope, which special structure must be regarded as an organic complication undesirable for our purpose.

Haeckel was the first to point out the most fascinating of all primitive beings; and he was the first also to recognize their true import in biology. He named them, on account of the entire homogeneity of their structure, Monera. It is now well known that monera consist of nothing but a flake or globule of uniform viscid material. Yet these unorganized specks of matter are most truly alive, for they are seen to move, to nourish themselves, to react on outward impressions, and to propagate their kind.

Here, then, we have all the fundamental properties of life, without any of its morphological complications. By dispensing, for once, with all elaborate equipment, and by executing her principal performances with such deliberate distinctiveness and openness, it is as if Nature were here purposely inviting us to penetrate her vital mysteries.

If we can only gain an actual insight into the conditions upon which

these various well-defined vital phenomena are dependent, if we can succeed in establishing their direct relation, their immediate continuity with the rest of the world, then we cannot possibly be far from having reached the solution of the first phase of our problem.

There can be no manner of doubt that the secrets of the origin of vitality, and of the rise of organization, must all lie encompassed in these most unsophisticated dots of living material. What more enticing prospect for scientific investigation could be found? The nature of vital phenomena, if not disclosed even here in its plainest mode of manifestation, must ever remain incomprehensible. It is the fundamental truth of living reality, in all its native force, which in this unorganized and quickened matter appeals to our understanding, and it needs but candor, simplicity, and courage, to become initiated into the mystery of vitality. Let us, then, endeavor to cast away the incumbrance of so much foreknowledge, misleading as it has proved. If at all attainable, here it is, with our diminutive specimens of vitality, that true insight is to be gained. At any rate, we cannot leave the inquiry till we know, or till we have become fully convinced, that vital phenomena, even in their elements, are impervious to human knowledge.

Having for the last four years concentrated his whole attention on the manifestations of primitive life, and reached results which he deems important, the present writer, in a succeeding and fuller article, will attempt to convey to the general reader some idea of what he has gained by these studies.

COMPOSITE PORTRAITS.[1]

By FRANCIS GALTON, F. R. S.

I SUBMIT to the Anthropological Institute my first results in carrying out a process that I suggested last August in my Presidential Address to the Anthropological Subsection of the British Association at Plymouth, in the following words:

"Having obtained drawings or photographs of several persons alike in most respects, but differing in minor details, what sure method is there of extracting the typical characteristics from them? I may mention a plan which had occurred both to Mr. Herbert Spencer and myself, the principle of which is to superimpose optically the various drawings and to accept the aggregate result. Mr. Spencer suggested to me in conversation that the drawings reduced to the same scale might be traced on separate pieces of transparent paper and secured one upon another, and then held between the eye and the light. I have attempted this with some success. My own idea was, to throw faint images of the several portraits, in succession, upon the same sensitized photographic plate. I may add that it is perfectly easy to superimpose optically two portraits by means of a

[1] Abstract of a paper read before the London Anthropological Institute, April 30, 1878.

stereoscope, and that a person who is used to handle instruments will find a common double eye-glass fitted with stereoscopic lenses to be almost as effectual and far handier than the boxes sold in shops."

Mr. Spencer, as he informed me, had actually devised an instrument, many years ago, for tracing mechanically longitudinal, transverse, and horizontal sections of heads on transparent paper, intending to superimpose them and to obtain an average result by transmitted light.

Since my address was published, I have caused trials to be made, and have found as a matter of fact that the photographic process of which I there spoke enables us to obtain with mechanical precision a generalized picture; one that represents no man in particular, but portrays an imaginary figure, possessing the average features of any given group of men. These ideal faces have a surprising air of reality. Nobody who glanced at one of them for the first time would doubt its being the likeness of a living person. Yet, as I have said, it is no such thing; it is the portrait of a type, and not of an individual.

I begin by collecting photographs of the persons with whom I propose to deal. They must be similar in attitude and size, but no exactness is necessary in either of these respects. Then by a simple contrivance I make two pinholes in each of them, to enable me to hang them up one in front of the other, like a pack of cards, upon the same pair of pins, in such a way that the eyes of all the portraits shall be as nearly as possible superimposed; in which case the remainder of the features will also be superimposed nearly enough. These pinholes correspond to what are technically known to printers as "register-marks." They are easily made; a slip of brass or card has an aperture cut out of its middle, and threads are stretched from opposide sides, making a cross.

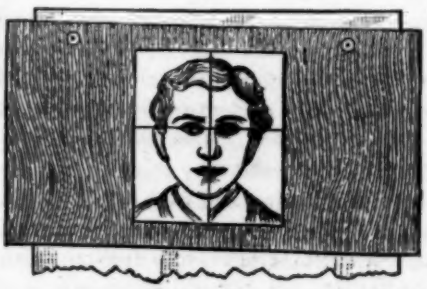

FIG. 1.

Two small holes are drilled in the plate, one on either side of the aperture. The slip of brass is laid on the portrait with the aperture over its face. It is turned about until one of the cross-threads cuts the pupils of both the eyes, and it is further adjusted until the other thread divides the interval between the pupils in two equal parts. Then it is held firmly, and a prick is made through each of the holes. The portraits being thus arranged, a photographic camera is directed upon

them. Suppose there are eight portraits in the pack, and that under existing circumstances it would require an exposure of eighty seconds to give an exact photographic copy of any one of them. The general principle of proceeding is this, subject in practice to some variation of details, depending on the different brightness of the several portraits: We throw the image of each of the eight portraits in turn upon the same part of the sensitized plate for ten seconds. Thus, portrait No. 1

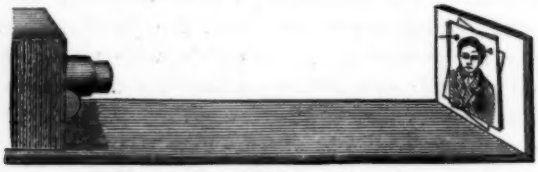

FIG. 2.

is in the front of the pack; we take the cap off the object-glass of the camera for ten seconds, and afterward replace it. We then remove No. 1 from the pins, and No. 2 appears in the front; we take off the cap a second time for ten seconds, and again replace it. Next we remove No. 2, and No. 3 appears in the front, which we treat as its predecessors, and so we go on to the last of the pack. The sensitized plate will now have had its total exposure of eighty seconds; it is then developed, and the print taken from it is the generalized picture of which I speak. It is a composite of eight component portraits. Those of its outlines are sharpest and darkest that are common to the largest number of the components; the purely individual peculiarities leave little or no visible trace. The latter being necessarily disposed equally on both sides of the average, the outline of the composite is the average of all the components. It is a band, and not a fine line, because the outlines of the components are seldom exactly superimposed. The band will be darkest in its middle whenever the component portraits have the same general type of features, and its breadth or amount of blur will measure the tendency of the components to deviate from the common type. This is so for the very same reason that the shot-marks on a target are more thickly disposed near the bull's-eye than away from it, and in a greater degree as the marksmen are more skillful. All that has been said of the outlines is equally true as regards the shadows; the result being that the composite represents an averaged figure, whose lineaments have been softly drawn. The eyes come out with appropriate distinctness, owing to the mechanical conditions under which the components were hung.

A composite portrait represents the picture that would rise before the mind's eye of a man who had the gift of pictorial imagination in an exalted degree. But the imaginative power even of the highest artists is far from precise, and is so apt to be biased by special cases that may have struck their fancies, that no two artists agree in any of their typi-

cal forms. The merit of the photographic composite is its mechanical precision, being subject to no errors beyond those incidental to all photographic productions.

I submit several composites made for me by Mr. H. Reynolds. The first set of portraits are those of criminals convicted of murder, manslaughter, or robbery accompanied with violence. It will be observed that the features of the composites are much better looking than those of the components. The special villainous irregularities in the latter have disappeared, and the common humanity that underlies them has prevailed. They represent, not the criminal, but the man who is liable to fall into crime. All composites are better looking than their components, because the averaged portrait of many persons is free from the irregularities that variously blemish the looks of each of them. I selected these for my first trials because I happened to possess a large collection of photographs of criminals through the kindness of Sir Edmund Du Cane, the Director-General of Prisons, for the purpose of investigating criminal types. They were peculiarly adapted to my present purpose, being all made of about the same size and taken in much the same attitudes. It was while endeavoring to elicit the principal criminal types by methods of optical superimposition of the portraits, such as I had frequently employed with maps and meteorological traces,[1] that the idea of composite figures first occurred to me.

The other set of composites are made from pairs of components. They are selected to show the extraordinary facility of combining almost any two faces whose proportions are in any way similar.

It will, I am sure, surprise most persons to see how well-defined these composites are. When we deal with faces of the same type, the points of similarity far outnumber those of dissimilarity, and there is a much greater resemblance between faces generally than we who turn our attention to individual differences are apt to appreciate. A traveler, on his first arrival among people of a race very different from his own, thinks them closely alike, and a Hindoo has much difficulty in distinguishing one Englishman from another.

The fairness with which photographic composites represent their components is shown by six of the specimens. I wished to learn whether the order in which the components were photographed made any material difference in the result, so I had three of the portraits arranged successively in each of their six possible combinations. It will be observed that four at least of the six composites are closely alike. I should say that in each of this set the last of the three components was always allowed a longer exposure than the second, and the second than the first, but it is found better to allow an equal time to all of them.

The stereoscope, as I stated last August in my address at Plymouth,

[1] "Conference at the Loan Exhibition of Scientific Instruments," 1878. Chapman & Hall. Physical Geography Section, p. 312. "On Means of combining Various Data in Maps and Diagrams," by Francis Galton, F. R. S.

affords a very easy method of optically superimposing two portraits, and I have much pleasure in quoting the following letter, pointing out this fact as well as some other conclusions at which I also had arrived. The

FIG. 3.

The accompanying woodcut is as fair a representation of one of the composites as is practicable in ordinary printing. It was photographically transferred to the wood, and the engraver has used his best endeavor to translate the shades into line engraving. This composite is made out of only three components, and its threefold origin is to be traced in the ears, and in the buttons to the vest. To the best of my judgment the original photograph is a very exact average of its components; not one feature in it appears identical with that of any one of them, but it contains a resemblance to all, and is not more like to one of them than to another. However, the judgment of the wood-engraver is different. His rendering of the composite has made it exactly like one of its components, which, it must be borne in mind, he had never seen. It is just as though an artist drawing a child had produced a portrait closely resembling its deceased father, having overlooked an equally strong likeness to its deceased mother, which was apparent to its relatives. This is to me a most striking proof that the composite is a true combination. (I trust that the beauty of the woodcut will not be much diminished by the necessarily coarse process of newspaper-printing.)

letter was kindly forwarded to me by Mr. Darwin; it is dated last November, and was written to him by Mr. A. L. Austin from New Zealand, thus affording another of the many curious instances of two persons being independently engaged in the same novel inquiry at nearly the same time, and coming to similar results:

"INVERCARGILL, NEW ZEALAND, *November* 6, 1877.

"To CHARLES DARWIN, ESQ.

"SIR: Although a perfect stranger to you, and living on the reverse side of the globe, I have taken the liberty of writing to you on a small discovery I have made in binocular vision in the stereoscope. I find by taking two ordinary *carte-de-visite* photos of two different persons' faces, the portraits being about the same sizes, and looking about the same direction, and placing them in a stereoscope, the faces blend into one in a most remarkable manner, producing in the case of some ladies' portraits in every instance a *decided improvement* in beauty. The pictures were not taken in a binocular camera, and therefore do not stand out well, but, by moving one or both until the eyes coincide in the stereoscope, the

pictures blend perfectly. If taken in a binocular camera for the purpose, each person being taken on one-half of the negative, I am sure the results would be still more striking. Perhaps something might be made of this in regard to the expression of emotions in man and the lower animals, etc. I have not time or opportunities to make experiments, but it seems to me something might be made of this by photographing the faces of different animals, different races of mankind, etc. I think a stereoscopic view of one of the ape tribe and some low-caste human face would make a very curious mixture; also in the matter of crossing of animals and the resulting offspring. It seems to me something also might result in photos of husband and wife and children, etc. In any case the results are curious, if it leads to nothing else. Should this come to anything, you will no doubt acknowledge myself as suggesting the experiment, and perhaps send me some of the results. If not likely to come to anything, a reply would much oblige me. Yours very truly,

"A. L. AUSTIN, C. E., F. R. A. S."

Dr. Carpenter informs me that the late Mr. Appold, the mechanician, used to combine two portraits of himself, under the stereoscope. The one had been taken from an assumed stern expression, the other with a smile, and this combination produced a curious and effective blending of the two.

Convenient as the stereoscope is, owing to its accessibility, for determining whether any two portraits are suitable in size and attitude to form a good composite, it is nevertheless a makeshift and imperfect way of attaining the required result. It cannot of itself combine two images; it can only place them so that the office of attempting to combine them may be undertaken by the brain. Now the two separate impressions received by the brain through the stereoscope do not seem to me to be relatively constant in their vividness, but sometimes the image seen by the left eye prevails over that seen by the right, and *vice versa*. All the other instruments I am about to describe accomplish that which the stereoscope fails to do; they create true optical combinations. As regards other points in Mr. Austin's letter, I cannot think that the use of a binocular camera for taking the two portraits intended to be combined into one by the stereoscope would be of importance. All that is wanted is that the portraits should be nearly of the same size. In every other respect I cordially agree with Mr. Austin.

The best instrument I have as yet contrived and used for optical superimposition is a "double-image prism" of Iceland spar. The latest that I have had were procured for me by Mr. Tisley, optician, 172 Brompton Road. It has a clear aperture of a square, half an inch in the side, and when held at right angles to the line of sight will separate the ordinary and extraordinary images to the amount of two inches, when the object viewed is held at seventeen inches from the eye. This is quite sufficient for working with *carte-de-visite* portraits. One image is quite achromatic, the other shows a little color. The divergence may be varied and adjusted by inclining the prism to the line of sight. By its means the ordinary image of one component is thrown upon the

extraordinary image of the other, and the composite may be viewed with the naked eye or through a lens of long focus, or through an opera-glass (a telescope is not so good) fitted with a sufficiently long draw-tube to see an object at that short distance with distinctness. Portraits

FIG. 4.

FIG. 5.

FIG. 6.

Fig. 4 shows the simple apparatus which carries the prism, and on which the photograph is mounted. The former is set in a round box which can be rotated in the ring at the end of the arm, and can be clamped when adjusted. The arm can be rotated, and can also be pulled out or in if desired, and clamped. The floor of the instrument is overlaid with cork covered with black cloth, on which the components can easily be fixed by drawing-pins. When using it one portrait is pinned down and the other is moved near to it, overlapping its margin if necessary, until the eye looking through the prism sees the required combination; then the second portrait is pinned down also. It may now receive its register-marks from needles fixed in a hinged arm, and this is a more generally applicable method than the plan with cross-threads, already described, as any desired feature—the nose, the ear, or the hand—may thus be selected for composite purposes. Let *A*, *B*, *C*, . . . *Y*, *Z*, be the components. *A* is pinned down, and *B*, *C*, . . . *Y*, *Z*, are successively combined with *A*, and registered. Then, before removing *Z*, take away *A* and substitute any other of the already registered portraits, say *B*, by combining it with *Z*; lastly, remove *Z* and substitute *A* by combining it with *B*, and register it.

Fig. 5 shows one of three similarly-jointed arms, which clamp on to the vertical rod. Two of these carry a light frame covered with cork and cloth, and the other carries Fig. 6, which is a frame having lenses of different powers set into it, and on which, or on the third frame, a small mirror, inclined at 45°, may be laid. When a portrait requires foreshortening it can be pinned on one of these frames and be inclined to the line of sight; when it is smaller than its fellow it can be brought nearer to the eye and an appropriate lens interposed; when a right-sided profile has to be combined with a left-handed one, it must be pinned on one of the frames and viewed by reflection from the mirror in the other. (The apparatus I have drawn is roughly made, and, being chiefly of wood, is rather clumsy, but it acts well.)

of somewhat different sizes may be combined by placing the larger one farther from the eye, and a long face may be fitted to a short one by inclining and foreshortening the former. The slight fault of focus thereby occasioned produces little or no sensible ill-effect on the appearance of the composite.

The front and profile faces of two living persons sitting side by side or one behind the other, can be easily superimposed by a double-image prism. Two such prisms, set one behind the other, can be made

to give four images of equal brightness, occupying the four corners of a rhombus whose acute angles are 45°. Three prisms will give eight images; but this is practically not a good combination, the images fail in distinctness, and are too near together for use. Again, each lens of a stereoscope of long focus can have one or a pair of these prisms attached to it, and four or eight images may be thus combined.

Another instrument I have made consists of a piece of glass inclined at a very acute angle to the line of sight, and of a mirror beyond it, also inclined, but in the opposite direction to the line of sight. Two rays of light will therefore reach the eye from each point of the glass; the one has been reflected from its surface, and the other has been first reflected from the mirror, and then transmitted through the glass. The glass used should be extremely thin, to avoid the blur due to double reflections; it may be a selected piece from those made to cover microscopic specimens. The principle of the instrument may be further developed by interposing additional pieces of glass successively less inclined to the line of sight, and each reflecting a different portrait.

I have tried many other plans; indeed, the possible methods of optically superimposing two or more images are very numerous. Thus I have used a sextant (with its telescope attached); also strips of mirrors placed at different angles and their several reflections simultaneously viewed through a telescope. I have also used a divided lens, like two stereoscopic lenses brought close together, in front of the object-glass of a telescope.

I have not yet had an opportunity of superimposing images by placing glass negatives in separate magic-lanterns, all converging upon the same screen; but this or even a simple dioramic apparatus would be very suitable for exhibiting composite effects to an audience, and if the electric light were used for illumination, the effect on the screen could be photographed at once. It would also be possible to construct a camera with a long focus, and many slightly-divergent object-glasses, each throwing an image of a separate glass negative upon the same sensitized plate.

The uses of composite portraits are many. They give us typical pictures of different races of men, if derived from a large number of individuals of those races taken at random. An assurance of the truth of any of our pictorial deductions is to be looked for in their substantial agreement when different batches of components have been dealt with, this being a perfect test of truth in all statistical conclusions. Again, we may select prevalent or strongly-marked types from among the men of the same race, just as I have done with two of the types of criminals by which this memoir is illustrated.

Another use of this process is to obtain by photography a really good likeness of a living person. The inferiority of photographs to the best works of artists, so far as resemblance is concerned, lies in

their catching no more than a single expression. If many photographs of a person were taken at different times, perhaps even years apart, their composite would possess that in which a single photograph is deficient. I have already pointed out the experience of Mr. Appold to this effect. The analytical tendency of the mind is so strong that, out of any tangle of superimposed outlines, it persists in dwelling preferably on some one of them, singling it out and taking little heed of the rest. On one occasion it will select one outline, on another a different one. Looking at the patterns of the papered walls of our room we see, whenever our fancy is active, all kinds of forms and features; we often catch some strange combination which we are unable to recall on a subsequent occasion, while later still it may suddenly flash full upon us. A composite portrait would have much of this varied suggestiveness.

A further use of the process would be to produce, from many independent portraits of an historical personage, the most probable likeness of him. Contemporaneous statues, medals, and gems, would be very suitable for the purpose, photographs being taken of the same size, and a composite made from them. It will be borne in mind that it is perfectly easy to apportion different "weights" to the different components. Thus, if one statue be judged to be so much more worthy of reliance than another that it ought to receive double consideration in the composite, all that is necessary is to double either the time of its exposure or its illumination.

The last use of the process that I shall mention is of great interest as regards inquiries into the hereditary transmission of features, as it enables us to compare the average features of the product with those of the parentage. A composite of all the brothers and sisters in a large family would be an approximation to what the average of the product would probably be if the family were indefinitely increased in number, but the approximation would be closer if we also took into consideration those of the cousins who inherited the family likeness. As regards the parentage, it is by no means sufficient to take a composite of the two parents; the four grandparents and the uncles and aunts on both sides should be also included. Some statistical inquiries I published on the distribution of ability in families[1] give provisional data for determining the weight to be assigned in the composite to the several degrees of relationship. I should, however, not follow those figures in the present case, but would rather suggest for the earlier trials, first to give equal "weights" to the male and female sides; thus the father and a brother of the male parent would count equally with the father and a brother of the female parent. Secondly, I should "weight" each parent as 4, and each grandparent and each uncle and aunt as 1; again, I should weight each brother and sister as 4, and each of those cousins as 1 who inherited any part of the like-

[1] "Hereditary Genius," p. 317. Column D. Macmillan, 1869.

ness of the family in question. The other cousins I should disregard. The weights, as previously mentioned, would be bestowed by giving proportionate periods of exposure.[1]

Composites on this principle would undoubtedly aid the breeders of animals to judge of the results of any proposed union better than they are able to do at present, and in forecasting the results of marriages between men and women they would be of singular interest and instruction. Much might be learned merely by the frequent use of the double-image prism, as described above, which enables us to combine the features of living individuals when sitting side by side into a single image.

I have as yet had few opportunities of developing the uses of the composite photographic process, it being difficult without much explanation to obtain the requisite components. Indeed, the main motive of my publishing these early results is to afford that explanation, and to enable me to procure a considerable variety of materials to work upon. I especially want sets of family photographs, all as nearly as possible of the same size and taken in the same attitudes. The size I would suggest for family composites is that which gives one-half of an inch interval between the pupil of the eye and the line that separates the two lips. The attitudes about which there can be no mistake are: full face, an exact profile, say, always showing the right side of the face, and an exact three-quarters, always showing the left; in this, the outer edge of the right eyelid will be only just in sight. In each case the latter should look straight before him. Such portraits as these go well into *cartes de visite*, and I trust that not a few amateur photographers may be inclined to make sets of all the members of their family, young and old, and of both sexes, and to try composites of them on the principles I have described. The photographs used for that purpose need not be in the least injured, for the register marks may be made in the case into which they are slipped, and not in the photographs themselves.—*Nature.*

[1] Example: There are 5 brothers or sisters and 5 cousins whose portraits are available; the total period of desired exposure is 100 seconds. $5 \times 4 + 5 = 25$; $\frac{100}{25} = 4$; which gives $4 \times 4 = 16$ seconds for each brother or sister, and 4 seconds for each cousin ($5 \times 16 + 5 \times 4 = 100$).

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

By C. S. PEIRCE,
ASSISTANT IN THE UNITED STATES COAST SURVEY.

SIXTH PAPER.—DEDUCTION, INDUCTION, AND HYPOTHESIS.

I.

THE chief business of the logician is to classify arguments; for all testing clearly depends on classification. The classes of the logicians are defined by certain typical forms called syllogisms. For example, the syllogism called *Barbara* is as follows:

S is M; M is P:
Hence, S is P.

Or, to put words for letters—

Enoch and Elijah were men; all men die:
Hence, Enoch and Elijah must have died.

The "is P" of the logicians stands for any verb, active or neuter. It is capable of strict proof (with which, however, I will not trouble the reader) that all arguments whatever can be put into this form; but only under the condition that the *is* shall mean "*is* for the purposes of the argument" or "is represented by." Thus, an induction will appear in this form something like this:

These beans are two-thirds white;
But, the beans in this bag are (represented by) these beans;
∴ The beans in the bag are two-thirds white.

But, because all inference may be reduced in some way to *Barbara*, it does not follow that this is the most appropriate form in which to represent every kind of inference. On the contrary, to show the distinctive characters of different sorts of inference, they must clearly be exhibited in different forms peculiar to each. *Barbara* particularly typifies deductive reasoning; and so long as the *is* is taken literally, no inductive reasoning can be put into this form. *Barbara* is, in fact, nothing but the application of a rule. The so-called major premise lays down this rule; as, for example, *All men are mortal.* The other or minor premise states a case under the rule; as, *Enoch was a man.* The conclusion applies the rule to the case and states the result: *Enoch is mortal.* All deduction is of this character; it is merely the application of general rules to particular cases. Sometimes this is not very evident, as in the following:

All quadrangles are figures,
But no triangle is a quadrangle;
Therefore, some figures are not triangles.

But here the reasoning is really this:

Rule.—Every quadrangle is other than a triangle.
Case.—Some figures are quadrangles.
Result.—Some figures are not triangles.

Inductive or synthetic reasoning, being something more than the mere application of a general rule to a particular case, can never be reduced to this form.

If, from a bag of beans of which we know that $\frac{1}{3}$ are white, we take one at random, it is a deductive inference that this bean is probably white, the probability being $\frac{1}{3}$. We have, in effect, the following syllogism:

Rule.—The beans in this bag are $\frac{1}{3}$ white.
Case.—This bean has been drawn in such a way that in the long run the relative number of white beans so drawn would be equal to the relative number in the bag.
Result.—This bean has been drawn in such a way that in the long run it would turn out white $\frac{1}{3}$ of the time.

If instead of drawing one bean we draw a handful at random and conclude that about $\frac{1}{3}$ of the handful are probably white, the reasoning is of the same sort. If, however, not knowing what proportion of white beans there are in the bag, we draw a handful at random and, finding $\frac{1}{3}$ of the beans in the handful white, conclude that about $\frac{1}{3}$ of those in the bag are white, we are rowing up the current of deductive sequence, and are concluding a rule from the observation of a result in a certain case. This is particularly clear when all the handful turn out one color. The induction then is:

These beans were in this bag.
These beans are white.
∴ All the beans in the bag were white.

Which is but an inversion of the deductive syllogism.

Rule.—All the beans in the bag were white.
Case.—These beans were in the bag.
Result.—These beans are white.

So that induction is the inference of the *rule* from the *case* and *result*.

But this is not the only way of inverting a deductive syllogism so as to produce a synthetic inference. Suppose I enter a room and there find a number of bags, containing different kinds of beans. On the table there is a handful of white beans; and, after some searching, I find one of the bags contains white beans only. I at once infer as a

probability, or as a fair guess, that this handful was taken out of that bag. This sort of inference is called *making an hypothesis.* It is the inference of a *case* from a *rule* and *result.* We have, then—

DEDUCTION.

Rule.—All the beans from this bag are white.
Case.—These beans are from this bag.
∴ *Result.*—These beans are white.

INDUCTION.

Case.—These beans are from this bag.
Result.—These beans are white.
∴ *Rule.*—All the beans from this bag are white.

HYPOTHESIS.

Rule.—All the beans from this bag are white.
Result.—These beans are white.
∴ *Case.*—These beans are from this bag.

We, accordingly, classify all inference as follows:

Inference.

Deductive or Analytic. Synthetic.

Induction. Hypothesis.

Induction is where we generalize from a number of cases of which something is true, and infer that the same thing is true of a whole class. Or, where we find a certain thing to be true of a certain proportion of cases and infer that it is true of the same proportion of the whole class. Hypothesis is where we find some very curious circumstance, which would be explained by the supposition that it was a case of a certain general rule, and thereupon adopt that supposition. Or, where we find that in certain respects two objects have a strong resemblance, and infer that they resemble one another strongly in other respects.

I once landed at a seaport in a Turkish province; and, as I was walking up to the house which I was to visit, I met a man upon horseback, surrounded by four horsemen holding a canopy over his head. As the governor of the province was the only personage I could think of who would be so greatly honored, I inferred that this was he. This was an hypothesis.

Fossils are found; say, remains like those of fishes, but far in the interior of the country. To explain the phenomenon, we suppose the sea once washed over this land. This is another hypothesis.

Numberless documents and monuments refer to a conqueror called Napoleon Bonaparte. Though we have not seen the man, yet we can-

not explain what we have seen, namely, all these documents and monuments, without supposing that he really existed. Hypothesis again.

As a general rule, hypothesis is a weak kind of argument. It often inclines our judgment so slightly toward its conclusion that we cannot say that we believe the latter to be true; we only surmise that it may be so. But there is no difference except one of degree between such an inference and that by which we are led to believe that we remember the occurrences of yesterday from our feeling as if we did so.

II.

Besides the way just pointed out of inverting a deductive syllogism to produce an induction or hypothesis, there is another. If from the truth of a certain premise the truth of a certain conclusion would necessarily follow, then from the falsity of the conclusion the falsity of the premise would follow. Thus, take the following syllogism in *Barbara:*

Rule.—All men are mortal.
Case.—Enoch and Elijah were men.
∴ *Result.*—Enoch and Elijah were mortal.

Now, a person who denies this result may admit the rule, and, in that case, he must deny the case. Thus:

Denial of Result.—Enoch and Elijah were not mortal.
Rule.—All men are mortal.
∴ *Denial of Case.*—Enoch and Elijah were not men.

This kind of syllogism is called *Baroco*, which is the typical mood of the second figure. On the other hand, the person who denies the result may admit the case, and in that case he must deny the rule. Thus:

Denial of the Result.—Enoch and Elijah were not mortal.
Case.—Enoch and Elijah were men.
∴ *Denial of the Rule.*—Some men are not mortal.

This kind of syllogism is called *Bocardo*, which is the typical mood of the third figure.

Baroco and *Bocardo* are, of course, deductive syllogisms; but of a very peculiar kind. They are called by logicians indirect moods, because they need some transformation to appear as the application of a rule to a particular case. But if, instead of setting out as we have here done with a necessary deduction in *Barbara*, we take a probable deduction of similar form, the indirect moods which we shall obtain will be—

Corresponding to *Baroco*, an hypothesis;
and, Corresponding to *Bocardo*, an induction.

For example, let us begin with this probable deduction in *Barbara:*

Rule.—Most of the beans in this bag are white.
Case.—This handful of beans are from this bag.
∴ *Result.*—Probably, most of this handful of beans are white.

Now, deny the result, but accept the rule:

Denial of Result.—Few beans of this handful are white.
Rule.—Most beans in this bag are white.
∴ *Denial of Case.*—Probably, these beans were taken from another bag.

This is an hypothetical inference. Next, deny the result, but accept the case:

Denial of Result.—Few beans of this handful are white.
Case.—These beans came from this bag.
∴ *Denial of Rule.*—Probably, few beans in the bag are white.

This is an induction.

The relation thus exhibited between synthetic and deductive reasoning is not without its importance. When we adopt a certain hypothesis, it is not alone because it will explain the observed facts, but also because the contrary hypothesis would probably lead to results contrary to those observed. So, when we make an induction, it is drawn not only because it explains the distribution of characters in the sample, but also because a different rule would probably have led to the sample being other than it is.

But the advantage of this way of considering the subject might easily be overrated. An induction is really the inference of a rule, and to consider it as the denial of a rule is an artificial conception, only admissible because, when statistical or proportional propositions are considered as rules, the denial of a rule is itself a rule. So, an hypothesis is really a subsumption of a case under a class and not the denial of it, except for this, that to deny a subsumption under one class is to admit a subsumption under another.

Bocardo may be considered as an induction, so timid as to lose its amplifiative character entirely. Enoch and Elijah are specimens of a certain kind of men. All that kind of men are shown by these instances to be immortal. But instead of boldly concluding that all very pious men, or all men favorites of the Almighty, etc., are immortal, we refrain from specifying the description of men, and rest in the merely explicative inference that *some* men are immortal. So *Baroco* might be considered as a very timid hypothesis. Enoch and Elijah are not mortal. Now, we might boldly suppose them to be gods or something of that sort, but instead of that we limit ourselves to the inference that they are of *some* nature different from that of man.

But, after all, there is an immense difference between the relation of *Baroco* and *Bocardo* to *Barbara* and that of Induction and Hypothe-

sis to Deduction. *Baroco* and *Bocardo* are based upon the fact that if the truth of a conclusion necessarily follows from the truth of a premise, then the falsity of the premise follows from the falsity of the conclusion. This is always true. It is different when the inference is only probable. It by no means follows that, because the truth of a certain premise would render the truth of a conclusion probable, therefore the falsity of the conclusion renders the falsity of the premise probable. At least, this is only true, as we have seen in a former paper, when the word probable is used in one sense in the antecedent and in another in the consequent.

III.

A certain anonymous writing is upon a torn piece of paper. It is suspected that the author is a certain person. His desk, to which only he has had access, is searched, and in it is found a piece of paper, the torn edge of which exactly fits, in all its irregularities, that of the paper in question. It is a fair hypothetic inference that the suspected man was actually the author. The ground of this inference evidently is that two torn pieces of paper are extremely unlikely to fit together by accident. Therefore, of a great number of inferences of this sort, but a very small proportion would be deceptive. The analogy of hypothesis with induction is so strong that some logicians have confounded them. Hypothesis has been called an induction of characters. A number of characters belonging to a certain class are found in a certain object; whence it is inferred that all the characters of that class belong to the object in question. This certainly involves the same principle as induction; yet in a modified form. In the first place, characters are not susceptible of simple enumeration like objects; in the next place, characters run in categories. When we make an hypothesis like that about the piece of paper, we only examine a single line of characters, or perhaps two or three, and we take no specimen at all of others. If the hypothesis were nothing but an induction, all that we should be justified in concluding, in the example above, would be that the two pieces of paper which matched in such irregularities as have been examined would be found to match in other, say slighter, irregularities. The inference from the shape of the paper to its ownership is precisely what distinguishes hypothesis from induction, and makes it a bolder and more perilous step.

The same warnings that have been given against imagining that induction rests upon the uniformity of Nature might be repeated in regard to hypothesis. Here, as there, such a theory not only utterly fails to account for the validity of the inference, but it also gives rise to methods of conducting it which are absolutely vicious. There are, no doubt, certain uniformities in Nature, the knowledge of which will fortify an hypothesis very much. For example, we suppose that iron, titanium, and other metals exist in the sun, because we find in the solar

spectrum many lines coincident in position with those which these metals would produce; and this hypothesis is greatly strengthened by our knowledge of the remarkable distinctiveness of the particular line of characters observed. But such a fortification of hypothesis is of a deductive kind, and hypothesis may still be probable when such reënforcement is wanting.

There is no greater nor more frequent mistake in practical logic than to suppose that things which resemble one another strongly in some respects are any the more likely for that to be alike in others. That this is absolutely false, admits of rigid demonstration; but, inasmuch as the reasoning is somewhat severe and complicated (requiring, like all such reasoning, the use of A, B, C, etc., to set it forth), the reader would probably find it distasteful, and I omit it. An example, however, may illustrate the proposition: The comparative mythologists occupy themselves with finding points of resemblance between solar phenomena and the careers of the heroes of all sorts of traditional stories; and upon the basis of such resemblances they infer that these heroes are impersonations of the sun. If there be anything more in their reasonings, it has never been made clear to me. An ingenious logician, to show how futile all that is, wrote a little book, in which he pretended to prove, in the same manner, that Napoleon Bonaparte is only an impersonation of the sun. It was really wonderful to see how many points of resemblance he made out. The truth is, that any two things resemble one another just as strongly as any two others, if recondite resemblances are admitted. But, in order that the process of making an hypothesis should lead to a probable result, the following rules must be followed:

1. The hypothesis should be distinctly put as a question, before making the observations which are to test its truth. In other words, we must try to see what the result of predictions from the hypothesis will be.

2. The respect in regard to which the resemblances are noted must be taken at random. We must not take a particular kind of predictions for which the hypothesis is known to be good.

3. The failures as well as the successes of the predictions must be honestly noted. The whole proceeding must be fair and unbiased.

Some persons fancy that bias and counter-bias are favorable to the extraction of truth—that hot and partisan debate is the way to investigate. This is the theory of our atrocious legal procedure. But Logic puts its heel upon this suggestion. It irrefragably demonstrates that knowledge can only be furthered by the real desire for it, and that the methods of obstinacy, of authority, and every mode of trying to reach a foregone conclusion, are absolutely of no value. These things are proved. The reader is at liberty to think so or not as long as the proof is not set forth, or as long as he refrains from examining it. Just so, he can preserve, if he likes, his freedom of opinion in regard to the

propositions of geometry; only, in that case, if he takes a fancy to read Euclid, he will do well to skip whatever he finds with A, B, C, etc., for, if he reads attentively that disagreeable matter, the freedom of his opinion about geometry may unhappily be lost forever.

How many people there are who are incapable of putting to their own consciences this question, "Do I want to know how the fact stands, or not?"

The rules which have thus far been laid down for induction and hypothesis are such as are absolutely essential. There are many other maxims expressing particular contrivances for making synthetic inferences strong, which are extremely valuable and should not be neglected. Such are, for example, Mr. Mill's four methods. Nevertheless, in the total neglect of these, inductions and hypotheses may and sometimes do attain the greatest force.

IV.

Classifications in all cases perfectly satisfactory hardly exist. Even in regard to the great distinction between explicative and ampliative inferences, examples could be found which seem to lie upon the border between the two classes, and to partake in some respects of the characters of either. The same thing is true of the distinction between induction and hypothesis. In the main, it is broad and decided. By induction, we conclude that facts, similar to observed facts, are true in cases not examined. By hypothesis, we conclude the existence of a fact quite different from anything observed, from which, according to known laws, something observed would necessarily result. The former, is reasoning from particulars to the general law; the latter, from effect to cause. The former classifies, the latter explains. It is only in some special cases that there can be more than a momentary doubt to which category a given inference belongs. One exception is where we observe, not facts similar under similar circumstances, but facts different under different circumstances—the difference of the former having, however, a definite relation to the difference of the latter. Such inferences, which are really inductions, sometimes present nevertheless some indubitable resemblances to hypotheses.

Knowing that water expands by heat, we make a number of observations of the volume of a constant mass of water at different temperatures. The scrutiny of a few of these suggests a form of algebraical formula which will approximately express the relation of the volume to the temperature. It may be, for instance, that v being the relative volume, and t the temperature, the few observations examined indicate a relation of the form—

$$v = 1 + at + bt^2 + ct^3.$$

Upon examining observations at other temperatures taken at random, this idea is confirmed; and we draw the inductive conclusion that all

observations within the limits of temperature from which we have drawn our observations could equally be so satisfied. Having once ascertained that such a formula is possible, it is a mere affair of arithmetic to find the values of *a*, *b*, and *c*, which will make the formula satisfy the observations best. This is what physicists call an *empirical formula*, because it rests upon mere induction, and is not explained by any hypothesis.

Such formulæ, though very useful as means of describing in general terms the results of observations, do not take any high rank among scientific discoveries. The induction which they embody, that expansion by heat (or whatever other phenomenon is referred to) takes place in a perfectly gradual manner without sudden leaps or innumerable fluctuations, although really important, attracts no attention, because it is what we naturally anticipate. But the defects of such expressions are very serious. In the first place, as long as the observations are subject to error, as all observations are, the formula cannot be expected to satisfy the observations exactly. But the discrepancies cannot be due solely to the errors of the observations, but must be partly owing to the error of the formula which has been deduced from erroneous observations. Moreover, we have no right to suppose that the real facts, if they could be had free from error, could be expressed by such a formula at all. They might, perhaps, be expressed by a similar formula with an infinite number of terms; but of what use would that be to us, since it would require an infinite number of coefficients to be written down? When one quantity varies with another, if the corresponding values are exactly known, it is a mere matter of mathematical ingenuity to find some way of expressing their relation in a simple manner. If one quantity is of one kind—say, a specific gravity—and the other of another kind—say, a temperature—we do not desire to find an expression for their relation which is wholly free from numerical constants, since if it were free from them when, say, specific gravity as compared with water, and temperature as expressed by the centigrade thermometer, were in question, numbers would have to be introduced when the scales of measurement were changed. We may, however, and do desire to find formulas expressing the relations of physical phenomena which shall contain no more arbitrary numbers than changes in the scales of measurement might require.

When a formula of this kind is discovered, it is no longer called an empirical formula, but a law of Nature; and is sooner or later made the basis of an hypothesis which is to explain it. These simple formulæ are not usually, if ever, exactly true, but they are none the less important for that; and the great triumph of the hypothesis comes when it explains not only the formula, but also the deviations from the formula. In the current language of the physicists, an hypothesis of this importance is called a theory, while the term hypothesis is restricted to suggestions which have little evidence in their favor. There is some justice

in the contempt which clings to the word hypothesis. To think that we can strike out of our own minds a true preconception of how Nature acts, is a vain fancy. As Lord Bacon well says: "The subtlety of Nature far exceeds the subtlety of sense and intellect: so that these fine meditations, and speculations, and reasonings of men are a sort of insanity, only there is no one at hand to remark it." The successful theories are not pure guesses, but are guided by reasons.

The kinetical theory of gases is a good example of this. This theory is intended to explain certain simple formulæ, the chief of which is called the law of Boyle. It is, that if air or any other gas be placed in a cylinder with a piston, and if its volume be measured under the pressure of the atmosphere, say fifteen pounds on the square inch, and if then another fifteen pounds per square inch be placed on the piston, the gas will be compressed to one-half its bulk, and in similar inverse ratio for other pressures. The hypothesis which has been adopted to account for this law is that the molecules of a gas are small, solid particles at great distances from each other (relatively to their dimensions), and moving with great velocity, without sensible attractions or repulsions, until they happen to approach one another very closely. Admit this, and it follows that when a gas is under pressure what prevents it from collapsing is not the incompressibility of the separate molecules, which are under no pressure at all, since they do not touch, but the pounding of the molecules against the piston. The more the piston falls, and the more the gas is compressed, the nearer together the molecules will be; the greater number there will be at any moment within a given distance of the piston, the shorter the distance which any one will go before its course is changed by the influence of another, the greater number of new courses of each in a given time, and the oftener each, within a given distance of the piston, will strike it. This explains Boyle's law. The law is not exact; but the hypothesis does not lead us to it exactly. For, in the first place, if the molecules are large, they will strike each other oftener when their mean distances are diminished, and will consequently strike the piston oftener, and will produce more pressure upon it. On the other hand, if the molecules have an attraction for one another, they will remain for a sensible time within one another's influence, and consequently they will not strike the wall so often as they otherwise would, and the pressure will be less increased by compression.

When the kinetical theory of gases was first proposed by Daniel Bernoulli, in 1738, it rested only on the law of Boyle, and was therefore pure hypothesis. It was accordingly quite naturally and deservedly neglected. But, at present, the theory presents quite another aspect; for, not to speak of the considerable number of observed facts of different kinds with which it has been brought into relation, it is supported by the mechanical theory of heat. That bringing together bodies which attract one another, or separating bodies which repel one

another, when sensible motion is not produced nor destroyed, is always accompanied by the evolution of heat, is little more than an induction. Now, it has been shown by experiment that, when a gas is allowed to expand without doing work, a very small amount of heat disappears. This proves that the particles of the gas attract one another slightly, and but very slightly. It follows that, when a gas is under pressure, what prevents it from collapsing is not any repulsion between the particles, since there is none. Now, there are only two modes of force known to us, force of position or attractions and repulsions, and force of motion. Since, therefore, it is not the force of position which gives a gas its expansive force, it must be the force of motion. In this point of view, the kinetical theory of gases appears as a deduction from the mechanical theory of heat. It is to be observed, however, that it supposes the same law of mechanics (that there are only those two modes of force) which holds in regard to bodies such as we can see and examine, to hold also for what are very different, the molecules of bodies. Such a supposition has but a slender support from induction. Our belief in it is greatly strengthened by its connection with the law of Boyle, and it is, therefore, to be considered as an hypothetical inference. Yet it must be admitted that the kinetical theory of gases would deserve little credence if it had not been connected with the principles of mechanics.

The great difference between induction and hypothesis is, that the former infers the existence of phenomena such as we have observed in cases which are similar, while hypothesis supposes something of a different kind from what we have directly observed, and frequently something which it would be impossible for us to observe directly. Accordingly, when we stretch an induction quite beyond the limits of our observation, the inference partakes of the nature of hypothesis. It would be absurd to say that we have no inductive warrant for a generalization extending a little beyond the limits of experience, and there is no line to be drawn beyond which we cannot push our inference; only it becomes weaker the further it is pushed. Yet, if an induction be pushed very far, we cannot give it much credence unless we find that such an extension explains some fact which we can and do observe. Here, then, we have a kind of mixture of induction and hypothesis supporting one another; and of this kind are most of the theories of physics.

V.

That synthetic inferences may be divided into induction and hypothesis in the manner here proposed,[1] admits of no question. The utility and value of the distinction are to be tested by their applications.

[1] This division was first made in a course of lectures by the author before the Lowell Institute, Boston, in 1866, and was printed in the "Proceedings of the American Academy of Arts and Sciences," for April 9, 1867.

Induction is, plainly, a much stronger kind of inference than hypothesis; and this is the first reason for distinguishing between them. Hypotheses are sometimes regarded as provisional resorts, which in the progress of science are to be replaced by inductions. But this is a false view of the subject. Hypothetic reasoning infers very frequently a fact not capable of direct observation. It is an hypothesis that Napoleon Bonaparte once existed. How is that hypothesis ever to be replaced by an induction? It may be said that from the premise that such facts as we have observed are as they would be if Napoleon existed, we are to infer by induction that *all* facts that are hereafter to be observed will be of the same character. There is no doubt that every hypothetic inference may be distorted into the appearance of an induction in this way. But the essence of an induction is that it infers from one set of facts another set of similar facts, whereas hypothesis infers from facts of one kind to facts of another. Now, the facts which serve as grounds for our belief in the historic reality of Napoleon are not by any means necessarily the only kind of facts which are explained by his existence. It may be that, at the time of his career, events were being recorded in some way not now dreamed of, that some ingenious creature on a neighboring planet was photographing the earth, and that these pictures on a sufficiently large scale may some time come into our posession, or that some mirror upon a distant star will, when the light reaches it, reflect the whole story back to earth. Never mind how improbable these suppositions are; everything which happens is infinitely improbable. I am not saying that *these* things are likely to occur, but that *some* effect of Napoleon's existence which now seems impossible is certain nevertheless to be brought about. The hypothesis asserts that such facts, when they do occur, will be of a nature to confirm, and not to refute, the existence of the man. We have, in the impossibility of inductively inferring hypothetical conclusions, a second reason for distinguishing between the two kinds of inference.

A third merit of the distinction is, that it is associated with an important psychological or rather physiological difference in the mode of apprehending facts. Induction infers a rule. Now, the belief of a rule is a habit. That a habit is a rule active in us, is evident. That every belief is of the nature of a habit, in so far as it is of a general character, has been shown in the earlier papers of this series. Induction, therefore, is the logical formula which expresses the physiological process of formation of a habit. Hypothesis substitutes, for a complicated tangle of predicates attached to one subject, a single conception. Now, there is a peculiar sensation belonging to the act of thinking that each of these predicates inheres in the subject. In hypothetic inference this complicated feeling so produced is replaced by a single feeling of greater intensity, that belonging to the act of thinking the hypothetic conclusion. Now, when our nervous system is excited in a complicated way, there being a relation between the elements of the excitation, the

result is a single harmonious disturbance which I call an emotion. Thus, the various sounds made by the instruments of an orchestra strike upon the ear, and the result is a peculiar musical emotion, quite distinct from the sounds themselves. This emotion is essentially the same thing as an hypothetic inference, and every hypothetic inference involves the formation of such an emotion. We may say, therefore, that hypothesis produces the *sensuous* element of thought, and induction the *habitual* element. As for deduction, which adds nothing to the premises, but only out of the various facts represented in the premises selects one and brings the attention down to it, this may be considered as the logical formula for paying attention, which is the *volitional* element of thought, and corresponds to nervous discharge in the sphere of physiology.

Another merit of the distinction between induction and hypothesis is, that it leads to a very natural classification of the sciences and of the minds which prosecute them. What must separate different kinds of scientific men more than anything else are the differences of their *techniques*. We cannot expect men who work with books chiefly to have much in common with men whose lives are passed in laboratories. But, after differences of this kind, the next most important are differences in the modes of reasoning. Of the natural sciences, we have, first, the classificatory sciences, which are purely inductive—systematic botany and zoölogy, mineralogy, and chemistry. Then, we have the sciences of theory, as above explained—astronomy, pure physics, etc. Then, we have sciences of hypothesis—geology, biology, etc.

There are many other advantages of the distinction in question which I shall leave the reader to find out by experience. If he will only take the custom of considering whether a given inference belongs to one or other of the two forms of synthetic inference given on page 472, I can promise him that he will find his advantage in it, in various ways.

POISONS OF THE INTELLIGENCE—HASHEESH.[1]

By CHARLES RICHET.

HASHEESH is the extract of Indian hemp. This extract, mixed with different aromatics and vegetable oils, forms *dawamesk*, a sort of nauseous confection taken before a meal. Then there is the hasheesh smoked in pipes or in cigarettes, and this is the form in which the drug is most commonly taken in the East. The aqueous extract is known as *hafioun;* it is more active than the other two preparations. It takes nearly four parts of dawamesk to make one of hafioun. It is

[1] Translated and condensed by J. Fitzgerald, A. M.

very difficult to find out any more concerning the Oriental modes of preparing hasheesh; still, though our pharmaceutical information be insufficient, we are pretty familiar with the psychic effects of the drug. I have taken it myself again and again in various doses, and have administered it to many of my friends, and whatever I shall have to say concerning its properties will be based upon my own observations. Taken in moderate doses, it produces a kind of intoxication that is very pleasant, highly advantageous for a correct knowledge of intellectual phenomena, and at the same time free from serious consequences. The worst that is to be expected when one takes either dawamesk or hafioun in suitable quantities is slight disorder of the digestion, and a little sense of heaviness and of cerebral excitation.

If one has not been told what to expect, the first effects of hasheesh pass by unnoticed; these consist of a certain motor and sensor excitability of the spinal cord. There is a twitching in the nape of the neck, the back and the legs, and a shivering that extends over the whole body. It is as though there were puffs of hot and cold air rising to the head; but withal there is a vague sense of comfortableness, and one finds himself in a state of great good-humor, as is the case of most persons after the absorption of a certain amount of alcohol. By degrees the excitation of the spinal cord produces effects that are more characteristic, as muscular exertion of every kind, walking, stretching, dancing, lifting heavy weights; but meantime the mind is calm. Suddenly, however, on hearing some chance remark, the patient is seized with a fit of laughing without any apparent cause, and this continues for a length of time. This having passed, he comes to himself again, and recognizes the first effects of the poison.

Ideas now come crowding on his brain, one following another with bewildering rapidity. Thoughts come and go without any apparent law of succession or concomitance, but in reality they are governed by the immutable laws of the association of ideas and impressions. The patient thinks the persons he sees around him very slow and dull. Language is not swift enough to give expression to his rapid thoughts. There is, as it were, an hypertrophy of ideas. What in the normal state would cause very trifling discomfort, now becomes an unbearable evil, and the patient cries and begs for commiseration. With the air of a tragic actor he will tell you that it rains, or that the wind blows. One's self-esteem is magnified, and he looks down with scorn upon the ignorance of others.

Thus, then, to say nothing as yet of the change in sensation, the moral person is entirely transformed. I am not aware that the resemblance of these phenomena to those of hysteria has ever been noticed. In general, hysterical women are very intelligent, with brilliant ideas and a lively imagination; but their mental activity labors under two defects, namely, the exaggeration of the feelings and the absence of will. The same thing is seen in the use of hasheesh.

But there are other phenomena that are still more characteristic of hasheesh, especially its effects on our notions of time and space. Under its influence, time seems to be of interminable length. Between two clearly-conceived ideas the patient descries a host of others that are indeterminate and incomplete, and of which he is only dimly conscious; but he is filled with admiration at their number and vastness. Now we measure time by the memory of the ideas that have passed through the mind, and hence an instant appears immensely long to one under the hasheesh influence. Suppose, as is common enough in the use of this drug, that in the space of one second fifty different thoughts enter the brain; now, since in the normal state it requires several minutes to conceive fifty different thoughts, the inference will be that many minutes have gone by. Seconds become years, and minutes become ages.

This illusion has no parallel; yet in dreaming, or rather in that intermediate state which is neither sleeping nor waking, we experience something similar. I recollect having been at work one day with a friend, and, as I felt drowsy, asking him to let me sleep for a few minutes. On awaking, I was assured by him that I had slept hardly a second; and yet in that brief time I had had a very complicated dream, and, in consequence of the multiplicity of my thoughts, the time had appeared to be of considerable length. So, if a person be awakened by some sudden, loud noise, he will oftentimes, in the fraction of a second, pass in imagination through scenes and adventures of a very complicated nature. A like illusion may be procured at will by shutting the eyes while one is riding in a carriage: under such circumstances the journey will appear to have no end; on opening the eyes from time to time, and observing the landmarks, the progress will seem to be extremely slow.

But in dreaming and in sleep this illusion as to the lapse of time is vague and ill-defined. Under the influence of hasheesh, on the contrary, it becomes singularly definite. Nor is the illusion of the sight less astonishing, which causes inconsiderable distances to appear enormously great. I do not know whether this illusion has been observed under any other conditions than those of hasheesh-poisoning, nor can I offer any rational explanation of it. It is difficult even to describe it. It causes a bridge, an avenue, to stretch out to unheard-of lengths. On going up a ladder, the rounds appear to reach up to the sky. A river whose opposite bank is in sight becomes an arm of the sea. And, besides these two illusions of space and time, which by-the-way often persist twenty-four hours or more, there are other illusions of the strangest kind imaginable. Hallucinations, on the contrary, are infrequent, though one remarkable instance has been observed by Dr. Moreau, of Tours.

It is oftentimes very hard to draw the distinction between illusion and hallucination, but nevertheless there is a difference between these two manifestations of morbid psychic activity. When an insane patient sees at his elbow a walking, talking spectre, he has an hallucination. But if in a dark forest, at night, one takes some deformed trunk for a

ghost, he has an illusion. Illusion presupposes an actual sensation, the perception of which is exaggerated and erroneous, whereas hallucination comes spontaneously without requiring a sensation to give rise to it. Now, under the hasheesh influence, the sensations are exaggerated so as to produce endless illusions. The slightest sound becomes a crash, and we hear the fall of waters, the roar of cataracts, the blare of trumpets, or brilliant harmonies. I have seen persons, naturally almost insensible to music, lifted by a few musical notes into an ecstasy such as we read of in the lives of saints. But, for a description of all these sensations, I would refer the reader to the brilliant pages of Théophile Gautier's "Club des Hachichins."

I will not go over ground trod by Gautier, but will content myself with touching upon another point of psychological interest. We will suppose the illusion to be stronger than anything noticed in the foregoing instances; that instead of being a simple disorder of the perceptive faculties, it affects the conceptive powers. Under normal conditions, external impressions awaken manifold ideas in our minds; besides the association of ideas, there is association of impressions with ideas. For instance, a certain taste, smell, or sound, gives rise to a multitude of conceptions that follow one another according to the direction we may be pleased to give them. The faculty of attention enables us to check the uprising of the conceptions called forth by the taste, smell, or sound. Often, while attention is fixed on an object, we neither hear nor see what is passing without. In reality we do see and hear, but these sensations are obliterated, and pass out of the mind without leaving a trace behind. In the use of hasheesh, in virtue of the loss of will, the intensity of the perceptions, and the excitation of the brain, every external impression calls forth a series of delirious conceptions, and there is no check.

Dr. Moreau lays great stress on the resemblance subsisting between these hasheesh illusions and the systematic delirium of the insane. In most lunatics the delirious idea has its origin in fact, in a sensation, a pain, an impression from without. This forms for them the logical basis of a system of erroneous judgments. If, for instance, they suffer from nausea or gastric pains, they say they have been poisoned; that their enemies have mixed poison with their food. Precisely the same thing is found in the use of hasheesh. Every sensation immediately calls forth an insane thought, or rather a thousand such thoughts. Hence it really appears as though the veil were rent in twain, and that by the use of this drug we are enabled to witness the mind itself at its work. The mysterious and silent travail which in the normal state produces our thoughts and judgments is no longer either mysterious or silent: we can see how the whole is connected, and can look on while ideas are being evolved. But, unfortunately, under the hasheesh influence one is no longer master of his own thoughts, and must, perforce, follow them in their disorderly course. Here we observe close resemblance between

the three states of dreaming, insanity, and hasheesh intoxication. In all these external impressions are all-powerful, and the mind is subject, unchecked, to the excitation of the senses.

One great difference between intoxication by hasheesh and that by alcohol and chloroform is that in the former, when the dose is light, memory is intact: one remembers with marvelous exactitude all that he saw, did, or said. But if the dose be strong, the loss of memory is complete; then, too, there is delirium, wild delirium. In such doses hasheesh is dangerous, though I do not think a single case of death from this cause has ever been recorded in Europe. But sometimes the delirium has continued for several days, and assumed serious proportions. No one should take hasheesh without having some person to care for him while under the influence of the drug; oftentimes the hasheesh gives such a sense of lightness and agility that a person will attempt to fly by leaping out of a window.

In the East hasheesh is in very general use. It is nearly always smoked in large pipes, which are passed from mouth to mouth. The smoke is very agreeable, possessing a peculiar aromatic odor. On entering certain Arab *cafés* at Cairo or at Damascus, one perceives this penetrating odor, which gently intoxicates even those who do not smoke. In this mild dose hasheesh produces a sort of sleepiness, during which external objects assume fantastic forms, and all is like a dream. The monotonous, nasal music has a gentle, tranquilizing effect during this sleep. On the walls of the *café* are rudely-pictured camels, grotesque human forms, or the surface is marked with lines, quadrangles, and triangles. In the minds of the hasheesh-smokers these rude pictures awaken delightful illusions, and they fancy themselves to be transported to Mohammed's paradise. To further amuse the indolence of the customers, a chanter drones out a long story, semi-religious, semi-heroic. The tale is in couplets, and between the couplets the music strikes up again its interminable rhythm. Now and then a smoker will rise staggering to his feet, and will give expression by yells to the delight with which he contemplates some fantastic image that he sees. The rest of the company then laugh uproariously, but anon will greet the last speaker with "Allah be with thee! Allah be praised!" Never shall I forget this spectacle, which, in a dark corner of the noisy bazaars of Damascus, with the dim light of a smoky lamp, to the sound of the tambourine and guitar with three cords, enabled me to understand one side of Oriental life.

SKETCH OF THOMAS ALVA EDISON.

By G. M. SHAW.

THIS remarkable inventor, of whom the public has recently heard so much, is still a young man, having been born in 1847 at Milan, Erie County, Ohio. His mother was of Scotch parentage, but born in Massachusetts; she was finely educated, literary and ambitious, and had been a teacher in Canada. Young Edison's only schooling came from his mother, who taught him spelling, reading, writing, and arithmetic. He lost his mother in 1862, but his father, a man of vigorous constitution, is still living, aged seventy-four. When he was seven years old, his parents removed to Port Huron, Michigan. The boy disliked mathematics, but was fond of reading, and, before he was twelve years old, had read the "Penny Cyclopædia," Hume's "England," and Gibbon's "Rome." He early took to the railroad, and became a newsboy on the Grand Trunk line, running into Detroit. Here he had access to a library, which he undertook to read through; but, after skimming over many hundred miscellaneous books, he adopted the plan of select reading on subjects of interest to him. Becoming interested in chemistry, he bought some chemicals, and fixed up a laboratory in one of the cars. An unfortunate combustion of phosphorus one day came near setting fire to the train, and the consequence was, that the conductor kicked the whole thing out. He had obtained the exclusive right to sell papers on the road, and employed four assistants; but, not satisfied with this, he bought a lot of second-hand type, and printed on the cars a little paper of his own, called the *Grand Trunk Herald*. Getting acquainted with the telegraph-operators along the road, he took a notion to become an operator himself. In his lack of means and opportunities, he resorted to the expedient of making his own apparatus at home. A piece of stove-wire, insulated by bottles, was made to do service as the line-wire. The wire for his electro-magnets he wound with rags, and in a similar way persevered until he had the crude elements of a telegraph; but the electricity being wanting, and as he could not buy a battery, he tried rubbing the fur of cats' backs, but says that electricity from this source was a failure for telegraphic purposes.

About two months afterward, as a train was switching on to a side-track at Mount Clemens Station, the station-agent's little boy, two years old, crept on to the track ahead of the cars. Edison saw the danger, sprang to the ground, and barely succeeded in saving the youngster. Its father, the station-master, being a poor man, could not show his gratitude by a money reward, but offered to teach young Edison telegraph-operating. He gladly seized the chance, and for five months we see him going back to Mount Clemens, at the close of his day's work, to labor nights in learning to be an operator. At the end

of this time he was able to go into the telegraph-office at Port Huron. Here he worked for six months, and then went to Stratford, Canada, as night-operator. He soon after went to Adrian, Michigan, where, in addition to his telegraph-office, he had a small shop and tools, to which he turned his hand at odd moments for the purpose of repairing instruments. This situation he lost by violating some rule while absorbed in his workshop, but in two months after appeared in Indianapolis, where he came out with his first invention, an automatic repeater—an arrangement for transferring a message from one wire to another without the aid of an operator. From this place he went in turn to Cincinnati, Memphis, Louisville, New Orleans, and back again to Cincinnati, where we find him in 1867, at the age of twenty, absorbed in projects of invention. His utter negligence of dress and appearance, his insatiable thirst for reading, and his enthusiastic attempts to solve what appeared to others impossible, together with his willingness to work at all hours of the day or night, earned him the name of "Looney," by which he was best known for many years. Reaching his office here one night and finding it "on strike," he took in the situation, and went to work, keeping it up all night, working to his utmost, receiving the press dispatches. For this act he was raised from a salary of $65 to $105 per month, and given the best line in the office. While here he conceived the idea, afterward perfected in Boston, of sending two messages at the same time over the same wire. His "everlasting experiments" were looked upon with disfavor by the management, and the imagined neglect of his work caused so much dissatisfaction that he quit the office and returned home to Port Huron.

Here he soon received a call from the manager of the Boston office to be the Boston operator on the "crack" New York wire. The manager knew him, but the appearance there of the very similitude of a green country gawky raised a shout of laughter at his expense, which almost unnerved him, and, to make the matter worse, before he had time to compose himself, he was shown his place to make a trial. The position was the dread of operators; the New York man was one of the fastest senders in the country, delighted in victims, and in this instance sat at his instrument with a grim satisfaction, waiting to open on the "new man," and chuckling with his Boston comrades over their expected fun. They commenced, and the New York man crowded his sending-speed to his utmost, with never a "break" by the new man receiving. At the end of the message, the astonished and exhausted New York operator adds, "Who the deuce *are* you, anyhow?" to which the new man at Boston promptly replies, "I'm Tom Edison—shake hands."

We can make but brief mention of a few of the many incidents connected with Mr. Edison's history. In the Boston office one of his first efforts was at "internal improvement." The office was infested with cockroaches. He set up an apparatus for their automatic de-

struction. Mr. Edison's *forte* is automatic contrivances. He arranged strips of metal around the bottom of the walls in the room, and connected them with the opposite poles of a battery, so that when the bugs stepped from one to the other, they closed the circuit and their lives at one operation, and made room for others.

In Boston Mr. Edison fixed up a small shop and continued his experiments, which he put into such practical shape that he saw more money in them than in his salary. He worked out the idea of his duplex telegraph, and went to Rochester in 1870 to test it between that place and Boston. The effort failed, though Mr. Edison says it ought to have succeeded. He then came to New York, scarcely knowing what to do next. He hung around the office of the Gold Indicator Company, studying their cumbersome apparatus. One day some part of it failed in a time of excitement; Mr. Edison offered to remedy it; he was laughed at incredulously; but the case was desperate, and he was allowed to try. He succeeded; and the managers, ready to perceive the value of such a man, made him superintendent. He introduced improved apparatus, invented the gold printer, put up a private line, and finally sold it to the Gold and Stock Company, together with his services, or the privilege of having the first option to buy his telegraphic inventions. He was now fully launched on a tide of success. To furnish his instruments, he established a factory in Newark, New Jersey, employing three hundred men. As a manufacturer he was not a success. If he had an order for any of his inventions, and, after having made a part or all of them, he invented an improvement, nothing would do but he must incorporate it, even though at his own expense. At last, finding that the close attention demanded by his manufacturing business was incompatible with the freedom demanded for invention, he abandoned it, and, two years ago, bought a site for an experiment-shop at Menlo Park, on the Pennsylvania Railroad, twenty-four miles from New York, a mere flag-station, with about a dozen houses, mostly his own and his workmen's.

On the crown of a knoll, and looking, for all the world, like a country meeting-house, minus the steeple, and with the addition of a porch, is a long two-story white frame building, in the middle of a little lot, surrounded by a white picket-fence. This is Mr. Edison's shop. On the ground-floor, as you enter, is a little front-office, from which a small library is partitioned off. Next is a large square room with glass cases filled with models of his inventions. In the rear of this is the machine-shop, completely equipped, and run with a ten-horse-power engine. The upper story occupies the length and breadth of the building, 100 × 25 feet, is lighted by windows on every side, and is occupied as a laboratory. The walls are covered with shelves full of bottles containing all sorts of chemicals. Scattered through the room are tables covered with electrical instruments, telephones, phonographs, microscopes, spectroscopes, etc. In the centre of the room is a rack full

of galvanic batteries. On one of the tables is a phonograph, run by steam-power, with a belt through the floor to the machine-shop, and beside it a copy of Poe's poems. In the rear of the room is a fine pipe-organ, with an open Moody and Sankey book on it. At the opposite end of the room stands Mr. Edison, telling the writer that there is no philosopher like Herbert Spencer, no writer like Victor Hugo, and no poet like Edgar A. Poe.

The Associated Press wires run through his laboratory, and anon he picks up his telephone and chats with Philadelphia, or with Prof. Barker, at the University of Pennsylvania. When visitors call to see him, they are most likely to inquire for Mr. Edison from the man himself—a boyish face, an unostentatious manner, a careless dress, and, in fact, the unchanged whole that formerly put in an appearance as the new man at the Boston office. The crowd of farm-boys that come over to see the wonderful talking-machine find him as ready to gratify their curiosity as the more pretentious "professor." While carrying on his manufacturing at Newark, he married, and—well, Dot and Dash are the nicknames of the little girl and boy that come every once in a while to "see the wheels go round."

We cannot here speak at length of his numerous inventions. He owns one hundred and fifty patents, but of these only about a dozen are of real value, the others are taken out to guard all approaches to the valuable patents. Among his pet patents are his quadruplex telegraphy, by which four messages may be sent at the same time over the same wire; his electric pen, for multiplying copies of letters or drawings, and which consists of a tubular pen in which a needle plays with a sewing-machine-like motion driven by electricity, which perforates the lines drawn with it, the perforated sheet being afterward inked and used in a press; the ink is pressed through the minute perforations and leaves on another sheet a finely-dotted tracing like the original. His carbon telephone and the phonograph are, perhaps, the most marvelous of his inventions.

When Mr. Gray brought out his musical telephone, which set students to experimenting in that direction, Mr. Edison was trying to improve the Reuss telephone, the invention of a German. Mr. Gray's apparatus gave promise of furnishing a method of multiplex telegraphy —a subject in which Mr. Edison, as we have seen, was interested. Between Mr. Gray and Mr. Edison an understanding was arrived at by which Mr. Edison was to leave Mr. Gray to carry out his invention unmolested in the direction of multiplex telegraphy; while Mr. Gray, on the other hand, would not interfere with Mr. Edison's attempt to make a speaking apparatus. While Mr. Edison had all but succeeded in making the electro-magnet telephone, Mr. Bell hit it and brought it out at the Centennial. Mr. Edison acknowledged himself fairly anticipated, and began to experiment with a view to finding a substance that would be elastic, so to speak, to the passage of a current

of electricity—that is, whose resistance to a current would vary with pressure. He began at one end of his stock of chemicals and tried every one of them—some two thousand—but met with no satisfactory result. Finally, when everything was exhausted, and he was looking around for what next to try, an assistant brought him a piece of broken lamp-chimney with an incrustation of lampblack: this was scraped off, pressed into a little cake, and tried. He had at last discovered what he was in search of. By placing it between two plates of metal connected with the opposite poles of the battery, and making one of the plates large, to receive the force of sound-waves, this varying pressure would make the carbon cake more or less elastic to the passage of the current of electricity, and the invention of the transmitting part of a new telephone—all his own—was complete. For the receiving part nothing was necessary but an ordinary electro-magnet with a diaphragm. Experiments with this "carbon telephone," as it is called, are unfolding every day its marvelous sensitiveness, as shown in its microphonic manifestations, which have been exciting so much wonder. No less successfully is it being brought to measure the pressure caused by infinitesimal heat—for instance, that received by us from the stars.

Coming, lastly, to the phonograph: while experimenting on an automatic transmitter in the early part of last winter, Mr. Edison tried tin-foil, instead of paper, to receive the indentations of the Morse recorder, and was surprised to see how readily it received them. These indentations, passing under another needle, were to repeat the message automatically to another wire. A few days after, while handling a telephone, the fancy seized him to fix a needle-point to a diaphragm, and see whether the vibration of the diaphragm when spoken against would cause the needle to prick his finger. It did. Then he wondered what sort of an indentation this would make in a slip of paper. He tried it, and, sure enough, there was the semblance of an indented track! What would be the effect of drawing this slip under the point again, following the working of the automatic transmitter? He tried that, and the result was one which almost made him wild. A sound like the stifled cry of words seeking birth came from the diaphragm. No sleep or food until he had made a grooved cylinder, put a piece of tin-foil instead of paper on it, attached the diaphragm, and shouted into it, when, upon turning the crank, the words came back with a marvelous elocution, and the phonograph was a success.

Mr. Edison has recently received the honorary title of Ph. D. from Union College.

EDITOR'S TABLE.

RELIGION AND SCIENCE AT VANDERBILT UNIVERSITY.

IT is not yet three years since we published an abridgment of the address delivered by Dr. Deems at the inauguration of Vanderbilt University, in Nashville. The speaker chose "Science and Religion" as a subject befitting the occasion, and from his intimate relations with the founder of the institution, and the share he is supposed to have had in determining the arrangement, his discourse was regarded as in some sense official and authoritative in foreshadowing the spirit of its administration. Dr. Deems said: "This recent cry of a conflict between Religion and Science is fallacious and mischievous to the interests of both science and religion, and would be most mournful if we did not believe that in the very nature of things it is to be ephemeral. Its genesis is to be traced to the weak foolishness of some professors of religion, and the weak wickedness of some professors of science." From which it is to be inferred that Vanderbilt University, at all events, would lend no countenance to this mischievous fallacy.

We protested at the time against regarding a controversy that has raged for centuries, that goes down to the very roots of human belief, and that is now more widely and intensely discussed than ever before, as "ephemeral." And we likewise protested against that superficial view of the causes of this conflict which ascribes them to the foolishness of religionists or the wickedness of scientists. We said that the cause of the warfare must be sought in the relations of the two subjects, meaning thereby the progressive nature of scientific knowledge and the fixedness of religious belief. That which is advancing must come in collision with that which is stationary, if the latter stands in the pathway of the former. And there are but two possible ways of avoiding collisions: either the moving body must stop, or the stationary body must get out of the way. Science will not cease to advance with its work, come what may, and let who will be hurt. It cannot pause, it cannot compromise. Its business is the study of Nature; its object to find out the utmost truth. It points to the vast body of modern knowledge which it has established, and to the conquest of Nature which that knowledge has conferred, as witnesses to the validity and beneficence of its great tasks, and as a presage of further triumphs in the future. The command is often and loudly given to Science to halt, but it would be just as sensible to order the Gulf Stream to halt, or to stay the course of Nature itself. The only question, then, is, whether Religion will take its unyielding theology out of the way, or wait to have it crushed and cast aside. At any rate, nothing is more futile than to resolve the conflict between Religion and Science into a mere question of decorum, propriety, or temper, between the parties engaged.

But, though much remains to be done before this warfare terminates, great progress has undoubtedly been made toward a better understanding, and more pacific relations between the parties. The spirit of liberality has already become so strong among the more intelligent portions of the community that demonstrations of bigotry on the part of theological bodies are pretty certain to incur a general condemnation. It was therefore not without con-

siderable surprise that we heard of the recent action of Vanderbilt University in repudiating the views of Dr. Deems's inaugural address. It has illustrated "the weak foolishness of some professors of religion" with a promptness and a shamelessness that shows how deep and intense is the living feeling of hostility to Science that animates large portions of the theological party. Vanderbilt University decides not to take its old traditions out of the way, but to fight the progress of Science by the same policy of bigotry, intolerance, and proscription, that has been employed for centuries by the same party in doing the same thing. The faculty of the institution have dismissed from his chair the Professor of Historical Geology and Zoölogy, on account of the opinions he holds concerning the antiquity of the human race.

The reader will find a notice in its place of Prof. Winchell's pamphlet on "Adamites and Preadamites," the publication of which has been made the occasion of his exclusion from the university. It will be seen that Prof. Winchell has simply accepted the views that now prevail in the scientific world regarding the time that men have inhabited the earth. The old notions upon the subject are now no longer entertained by intelligent men, because the scientific evidence is overwhelmingly against them. How long the human race has occupied the globe is an open question, but two things are settled: 1. That man has a much higher antiquity than theology has been in the habit of teaching, and has been currently believed; and, 2. That the investigation belongs entirely to science, and must be pursued and determined on the basis of scientific evidence. Prof. Winchell argues the subject strictly as a scientist, but in no spirit of antagonism to religion or to the authority of the Bible. His argument, indeed, is rather an attempt to harmonize the teachings of Scripture with the conclusions of science; a task which he had previously undertaken in a more general way, by the publication of an able book on "The Reconciliation of Science and Religion." But he has met with the not unusual treatment of peacemakers, who miscalculate the temper of the strife they would compose. The stupid Southern Methodists that control the university, it seems, can learn nothing. The fight over the antiquity of the earth has but just closed. The theologians battled long and fiercely against the geologists on this question, but have been so utterly routed that hardly a man of them can now be found who holds to the old belief. Prof. Silliman led the scientific movement upon that subject in this country, and so profound was the theological alarm that eminent doctors of divinity implored him with tears to desist from the impious crusade, because, if successful, it would be certain to destroy the Christian college with which he was associated. That institution had the good sense not to disturb the distinguished teacher in his work, but to abide by the results of investigation; and who can now be found so foolish as to regret its course? But half a century later, when an analogous question arises, Vanberbilt University adopts a different policy, follows the exploded precedents of past centuries, and puts forth its power to muzzle, repress, silence, and discredit the independent teachers of scientific truth.

There are features about this case that call for further strictures. The action of Vanderbilt University is not a little aggravating when we consider how the institution originated, and this consideration will throw some further light on the present phase of the conflict between Religion and Science. For there is a sense of honor in which it may be claimed that Mr. Vanderbilt's donations and endowments belong preeminently to science. How did he come by his wealth? It was by reaping the

magnificent harvests of profit that had grown up from the toilsome and unselfish labors of men of science. He owed his fortune to the enterprising use of steamships and railways, which were made possible by the steam-engine, a machine produced by the scientific labors of many discoverers and inventors, accumulated through generations. Mr. Vanderbilt's millions were the ultimate but none the less direct consequence of the self-sacrificing exertions of men of creative genius, working in poverty, obscurity, and difficulty, with heroic devotion, to construct a mechanism which they saw was to become potent in the future, and which has fulfilled their anticipations by revolutionizing modern society and giving to civilization the greatest impulse it has ever received from any single agency. It is therefore by no means a piece of far-fetched sentimentality to claim that, when the results of their work had ripened to almost fabulous acquisitions of wealth, some portion of it, at least, should be devoted to the advancement of the interests of science. Of course, Mr. Vanderbilt had the right—the legal right—to do what he pleased with his money; but if we recognize any higher consideration, any sentiment of justice, if we assume that there are such things as moral indebtedness and obligations of honor in the distribution of surplus wealth for public objects, then was the great harvester of millions by steam-travel bound to do something liberal and fair for the encouragement and promotion of the great, beneficent work of scientific investigation, which issues in such large advantages to the world.

And this was the more incumbent upon the rich custodian of the fruits of inventive genius, because so little of the scattered wealth of the rich finds its way into these channels. It is here that we see science and religion in practical rivalry, with the almost universal defeat of science. When rich old men and old women are about to distribute their wealth and die, science has but a sorry chance, and the Church generally has its own way. Where a dollar is got in such cases for the promotion of the study of Nature, and the elucidation of those laws upon which the amelioration of the condition of humanity most vitally depends, thousands are obtained by the representatives of ecclesiasticism for the propagation of faith. Religious societies abound in wealth, and scientific societies starve. If there is a scientific society in New York that owns a roof for shelter we do not know of it; yet, if we rightly remember the figures of the census, $53,000,000 are invested in its churches. We refer to these facts simply to illustrate the preponderance of theological influence and agencies over those that are available for the service of science, and to show the disadvantage at which science is placed in the struggle for means to carry on its work.

But although some portion, at least, of the immense wealth of Mr. Vanderbilt was morally mortgaged to the use of that class of men by whom it was in reality created, we are not aware that he ever in the slightest degree recognized such a claim. Some hundreds of thousands of dollars, however, were got out of him to found a sectarian university. But, though Mr. Vanderbilt had no care for science, one would have thought that the trustees and faculty of the institution which he endowed might have gracefully acknowledged that something was specially and honorably due from them to the interests of science, and have shaped the policy of the university accordingly. They might, at least, have been decently up to the times in the spirit of its management. An old educational establishment hampered by traditions, and running in the deep ruts of long-settled habit, has some excuse, perhaps, for guiding its course by the illiberal precedents of the past; but Vanderbilt University was a new organization,

opening fresh with the last quarter of the nineteenth century, and free to shape its course in full harmony with the enlightenment of the age. The spirit of the age and the progress of science, however, mean very little to the "weak foolishness" of the sort of Methodist theologians who have the institution in charge. They begin far behind the age, and are already old in bigotry and intolerance. They illustrate that hostility to science which belongs to low theological instincts, and now exhibit before the world the curious spectacle of an educational body into whose hands has fallen the wealth that the labors of scientific men have called into existence, and who use that wealth, not for the promotion and encouragement of scientific thought, but to hinder, defeat, and crush it.

AMERICAN INFLUENCE IN CIVILIZATION.

In his masterly discourse on "Civilization and Science," the second installment of which is herewith printed, Prof. Du Bois-Reymond refers to the question as to how civilization is to be measured, or by what tests we are to determine the height to which humanity has attained at any given time. Some say that this standard is furnished by the plastic arts, others by religion, others by literature, others by forms of government, and others by the diffusion of education. It will no doubt be a long while before parties entertaining different views upon this subject come to agreement; meantime, we hold, with the German professor, that the best criterion of the position which a nation has gained in the scale of civilization is the contributions which its men of thought have made toward the understanding and the conquest of Nature, and the popular and public appreciation that has been reached regarding this kind of intellectual labor. How does the community regard a man who gives his life to the investigation of the principles and laws, of the order of things, in the midst of which he finds himself placed, under the impulse, first of all, of the desire to know the truth, and, secondarily, to secure those large and benign results which come from the understanding of the method of Nature? What is the feeling entertained toward this class of men? Are they held in high honor, and encouraged in their labors, or are they treated with indifference, neglect, or contempt?

The question here is one of the degree of intellectual appreciation of different objects, and the relative intensity of the national feelings by which these objects are secured. In complex modern societies there will, of course, be found men devoted to different ideals, and a certain amount of popular favor or regard will be accorded to them all. But which of them receives the highest consideration, and what are the predominant national passions? Prof. Du Bois-Reymond, in considering the history of science in relation to civilization, calls our attention to the growth of the utilitarian spirit, which is gradually substituting immediate, practical, wealth-yielding studies for the more elevated, disinterested, and ennobling intellectual pursuits which have been cherished in past times. He points out that there is a decline of interest in this loftier work, under adverse pressures, that are increasing in intensity in the existing age, until they threaten the perversion and degradation of civilization itself. This influence he recognizes as strengthening in Europe, but as so predominating in this country that it is now generally known by the term Americanization. It is not so much that Americans are inappreciative of the real claims of liberal culture, or of the interests and requirements of scientific study, as that they are so overwhelmingly absorbed in material utilities that the finer and purer inspirations of study are dampened, smothered,

and suppressed. There may be a verbal recognition of the high claims of science, and many compliments turned to its heroic devotees, but the real feeling is evinced in exclamations of wonder at the curious eccentricity of mind that can forego the solid advantages of working for wealth, and prefer mental occupations that lead to empty honor and certain poverty.

An historical illustration will perhaps bring out more clearly this view, which is now coming to be regarded as so peculiarly American. There lived in England, in the last century, a man of science, named Henry Cavendish, who was born in 1731, and died in 1810. He was a gentleman of fine cultivation, an excellent mathematician, a profound electrician, and a most acute and ingenious chemist. He published many papers, containing results of recondite investigations and the most important discoveries. He was not only a great original thinker, but a most indefatigable and accurate experimenter, and one of his main lines of research was the chemical constitution of the atmosphere. He made no less than 500 analyses of the air, and it is to him that we owe our chief knowledge of the composition of the breathing medium. Now, there is not an American that will not commend all this as most proper and admirable. But there is another side to the case. Henry Cavendish was a man of enormous wealth, for which he cared absolutely nothing. He was one of the greatest proprietors of stock in the Bank of England, and when on one occasion his balance had accumulated to $350,000, and the directors, thinking it too much capital to lie unproductive, asked him if they should not invest it, he simply replied, "Lay it out, if you please." That small portion of his wealth which he could make use of in his investigations was so used, but he did not allow the remainder of it to divert his thoughts in the slightest degree from the unremitting prosecution of his scientific labors. He died worth $7,000,000, which was an immense sum of money at the beginning of this century, but he had not the slightest interest in those objects for which wealth is generally prized. Now, the whole case being given, to the eye of the typical American, Henry Cavendish will be regarded as a fool. "With all that money," the representative American would say, "I could keep a yacht, and a stud of fast horses, and build a church, and endow a college, and send a dozen missionaries to the heathen, and run a whole political campaign at my own expense; and you say this odd creature actually spent life in the smudge and stenches of a chemical laboratory, puttering with gases, and worried about the composition of the air!"

We do not here exaggerate the vulgar passion of Americans for money, and their relative and consequent indifference to other things. The country does not breed Cavendishes, and, if one should appear, he would stand a first-rate chance of getting into a lunatic asylum, as the bare fact of his indifference to riches would be held as *prima-facie* evidence of an unsound mind! The science that gives promise of immediate results, that can be turned into money, is appreciated; that which aims only at the extension of scientific truth wins little support. Prof. Tyndall devoted the profits of his lectures in this country, all the results of six months' labor, to assist in promoting the education of such young men as possess a talent for physical researches, and wish to qualify themselves for pursuing the work. It was a noble object, and one that had been nowhere provided for. Prof. Tyndall did not propose to found a school of research, but to help young men to avail themselves of the best institutions already existing for the acquisition of a special culture, the culture needed to carry on successful original inquiries. There have been many

applications to the trustees of the Tyndall fund for aid to young men of genius and aptitude for research, which, if it could have been granted, would have given them a career, and told in the most effectual way toward the extension of scientific knowledge. But the sum consecrated by Prof. Tyndall to this important end was not adequate to the wants of a nation. It was a large gift for a scientific professor without wealth, and, by the wise directions of the donor, it will be productive of large and lasting good, but it was given also to call emphatic attention to a neglected field of education, well worthy of the consideration of generous persons who desire to be certain that their benefactions will be well directed and confer real benefit. We do not say that Prof. Tyndall desired to set an example to anybody, but only that he contributed what was in his power to give an impulse to science in this country in a direction that was most needed; but how little Americans care for the object he had in view is shown by the fact that, amid all the multitudinous donations, gifts, and squanderings of wealth, on all sorts of objects, not a dollar has yet been added to the Tyndall fund for the promotion of scientific research by helping to train capable and ambitious young men for the work!

The country is characterized by the mad pursuit of wealth and the worship of riches; but this is not the worst, for along with this sordid passion there go the most vulgar and ignoble ideals of the uses of wealth. That ignorant, low-minded men, who become millionaires by inheritance or speculation, should spend their money in tawdry ostentation is to be expected; but the worst is, that gentlemen of sobriety, cultivation, and earnestness of character, who have large means at their disposal, should bestow them in charities that often do more harm than good, or in endowing professorships or building institutions that give notoriety to their names, and are of but little other use. Meantime, the country stands arraigned before the world for its lack of interest in those higher developments of thought which have given origin to civilization, and for giving their most powerful impulse to tendencies which threaten the deterioration of society and the degeneracy and debasement of civilization itself.

THE LATE MR. GEORGE S. APPLETON.

Since the appearance of the last number of this magazine, one of the company of brothers by whom it is published has passed away. Most of our readers have, no doubt, been informed by the newspapers that Mr. George S. Appleton died July 7th, at the age of fifty-seven. His unexpected death has been a painful shock to the relatives and intimate friends, by whom he was much beloved, and who are now left with only the consolatory memory of his many excellences of character. A few memorial words in regard to him will be appropriate in this place.

Mr. Appleton was a gentleman of marked mental accomplishments, such as are but rarely met with in the common walks of practical life. He was liberally educated, his early tastes and aptitudes for study being favored by attendance upon the best schools at home, and more completely developed by a four years' course at a German university. He was a wide and careful reader, but, as he designed to devote himself to the publishing business, he was specially interested in lingual studies, being a critical student of English and a master of the German, French, and Italian languages. He also gave early and prominent attention to the subject of art, was familiar with its history, and a discriminating critic in several of its principal departments.

But, though a man of refinement, of elegant culture, and fastidious tastes, Mr. Appleton did not allow æsthetic

feeling to narrow his nature, or to impair his interest in the more robust and solid work of modern science, and in those broad and serious inquiries which characterize the present age. He read with appreciation and heartily welcomed those powerful contributions to the advance of modern thought which have so deeply impressed the mind of our time, and which the house to which he belonged has done so much to make familiar to the reading public of this country. Never forgetting as a business-man that books are made to be sold, he also never forgot that they are the great means of popular enlightenment and elevation, and that publishers have a duty to society in respect to the character of the works which they disseminate.

It is, moreover, proper to remark here that Mr. Appleton was a man of deep and sincere religious feelings, and earnestly devoted to the duties of Christian worship; but his faith was too settled and serene to suffer any disturbance from that onward movement of knowledge which is so apt to excite alarm in men of restricted views and less firmness of religious conviction. Mr. Appleton illustrated in an eminent degree that largeness of sympathy and breadth of thought by which pure religious devotion is harmonized with intellectual progress, and with an intelligent solicitude for the amelioration of the secular interests of mankind. Conservative in disposition and habits, and no enthusiast, he was still much interested in all rational social improvements, and his influence was thrown in favor of every measure that can exalt and purify the public taste, and diffuse sound and useful information among the people. We are happy to add that he was a regular and critical reader of THE POPULAR SCIENCE MONTHLY, cordially approving its distinctive objects, and frequently favoring its conductors with valuable and important suggestions.

Mr. Appleton was a man of quiet and retiring manners, sensitive and modest to a degree that was often misinterpreted into coldness of nature; but those who knew him well understood that beneath a reserved and unobtrusive exterior there beat a warm heart that was ever animated by a kindly solicitude for the welfare of all who came within the reach of his influence. Although strict in the administration of business, he was watchful for those who needed care and encouragement, and many of his employés bear grateful testimony to his wise and kindly forethought in circumstances where the ministrations of genuine friendship are invaluable. The character of the man in his intercourse with his associates is well summed up by the remark of one who had been long and closely connected with him, that "his good words without flattery, and his honest comments without circumlocution," always inspired respect, confidence, and the truest esteem.

LITERARY NOTICES.

ADAMITES AND PREADAMITES, OR A POPULAR DISCUSSION CONCERNING THE REMOTE REPRESENTATIVES OF THE HUMAN SPECIES AND THEIR RELATION TO THE BIBLICAL ADAM. By ALEXANDER WINCHELL, LL. D. Syracuse, N. Y.: John T. Roberts. Pp. 52. Price, 15 cents.

THIS pamphlet is as readable as it is instructive. It is spicy in style, meaty in matter, and straightforward in its logic. As an introduction to the study of the antiquity of man, with an important side-bearing upon the old doctrines that have been entertained upon the subject, it is decidedly the best thing that we have met with. The discussion was originally contributed by Prof. Winchell to the *Northern Christian Advocate*, and now appears in ten chapters, the scope of which is indicated by their titles, as follows: Chapter I., "A Sagacious Dutchman;" II., "Dispersion of the Noachites;" III., "The Black Races not Adamites;" IV., "The Negro preadamic;" V.,

"The Negro preadamic"—continued; VI., "Scheme of Prehistoric Times;" VII., "Retrospective of Primeval Man in Europe;" VIII., "Antiquity of Man;" IX., "Origin of Man;" X., "Patriarchal Chronology."

It will be gathered from these heads of his arguments that Prof. Winchell is considering the question of man's antiquity upon the earth from the point of view of the common Christian belief that the whole human race is descended from the Scripture Adam. This he denies, affirming that the black races have a much higher antiquity than the period to which Adam is historically assigned, and who, in so far as he was a progenitor of races, must be regarded as only the father of the white or superior races. In the first chapter, entitled "A Sagacious Dutchman," Prof. Winchell calls attention to a small book that appeared in Paris in 1665, written by a Dutch ecclesiastic, named La Peyrère, on the unheard-of subject, indicated by its title of "Præadamitæ." Prof. Winchell says that La Peyrère was the first to promulgate to the world the idea of preadamite men. Of course, the sciences of ethnology and anthropology were at that time unknown, and the inquiry was therefore conducted entirely as a theological one—all questions being Bible-questions, and the meaning of the Bible being extracted according to the canons of grammar. The case was strongly made out by the Dutch doctor, and, although it could be argued in no other way at the time, Prof. Winchell takes occasion to characterize the method because there are plenty of learned men with whom it is still in vogue. Upon this point he says:

"There are doctors high in authority among us at this day, who maintain that grammatical structure and Hebrew usage are sufficient to light the way to the meaning of the darkest passages of revelation. I suppose a knowledge of Hebrew history and usages is admitted to shed its light upon interpretation, because the text is generally occupied with Jewish affairs. But the inspired writers have sometimes plunged into the midst of the profound and mysterious facts of science; why not, then, summon *all our knowledge* to the task of evoking the meaning of the text? I maintain, against the narrow and pernicious dogma that the Bible is sufficient everywhere to interpret itself, that, on the contrary, it was ordained to be interpreted under the concentrated light of all the learning which has been created by a God-given intelligence in man. I believe that the Bible was written for all time, and that its meaning is so deep and so rich that the accumulated learning of the latest generation of men will be unable to exhaust it."

Prof. Winchell then proceeds to discuss the question on its purely scientific basis, or in the light of modern facts, as disclosed by ethnological and archæological research. He concludes that the profound divergency of the races of mankind, as now known, and the demonstrated divergency that had been reached in the earliest historic periods, make the conclusion impossible that, if all the races of men had one origin, that origin can be brought within anything like the usually assigned period of six thousand years. Scientific evidence "forces this alternative conclusion upon us. If human beings have existed but six thousand years, then the human races had *separate beginnings*, as Agassiz long since maintained—each race in its own geographical area. But if all human beings are descended from one stock, then the starting-point was *more than six thousand years back*, as Huxley and the evolutionists generally maintain, and the Duke of Argyll and other anti-evolutionists equally maintain."

"Now, every person remains free to contemn a logical difficulty, and commiserate the unfortunate facts for being opposed to his belief. But my training has been such that logic and facts still command a degree of respect. Nor am I enough of an actor to play the part of an idiot. If I can avoid a difficulty I shall not dash out my brains against it. Let us consider Adam the father of the white and dusky races. These, then, are Adamites; and have a chronology extending back about six thousand years—perhaps all the time we require. The black races, then, are preadamites; and there is no objection to allowing all the time requisite for their divergence from some common stock. This view recognizes the unity of man—the possession of 'one blood' by all the races, one moral and intellectual nature, and one destiny; it recognizes Adam as the progenitor of the nations which form the theme of biblical history; it explains sundry biblical allusions and implications—for instance, the wife found by Cain in the land of Nod; Cain's fear of violence from others when condemned to the life of a 'fugitive and a vagabond;' the antithesis of the 'sons of God' and the 'daughters of men;' it validates the biblical chronology; it satisfies the demands of facts. The only objection outstanding against this view is the authority of an opinion formed two or three thousand years ago, by men who also held the opinion that witches ride broomsticks through the air, and that the stars were created two days

before Adam, though some of them are so distant that their light has been a hundred thousand years in reaching us!"

Prof. Winchell, of course, takes the ground that the older or black race is of an inferior type to the subsequent or, as he calls them, the Adamic races; and to the objection that the negro is not inferior to the white man he makes the following reply:

"1. If, when the sun is shining brightly, a man tells me it is dark, I can only pronounce him blind. The inferiority of the negro is a fact everywhere patent. I imply here only inferiority of intelligence, the instrument of self-helpfulness and of all civilization. I need not argue the fact; *circumspice*. But when this inferiority is conceded, we always hear the appeal to 'unfavorable conditions.' This leads me to note, 2. The African Continent has always been *favorably* conditioned. In the first place, it had a land connection with Asia and the seats of ancient civilization. It even had a remote civilization planted within its own borders; and the fires of Egyptian civilization have never been extinct; while for two thousand years the enlightenment of Europe has been within accessible distance. In the second place, the salubrity of the climate, the fertility of the soil, the vast hydrographic system of lakes and rivers, have all conspired to give the interior of the continent natural conditions unsurpassed by those of the site of any civilization which ever existed. Thirdly, the indigenous productions of Africa have supplied other conditions of human advancement. There exist two native cereals, negro millet and Caffre corn, which supply material for bread. There are the edible 'bread-roots' and also 'earth-nuts,' which are adequate to supply the daily food of whole villages. As to fruit-trees, there are the doom-palm, the oil-palm, and the 'butter-tree.' Moreover, for thousands of years the way has been open, as wide as the continent, for the introduction of the cereals of Asia. In fact, they have long been known to the natives; and maize, the manioc-root, and sugar-cane, as well as wheat and barley, have spread far toward the interior. There, too, have been domesticated animals, received, probably, from the Egyptians in a domesticated state; but no native animal has ever been domesticated. The Aryans of India employed the elephant as a beast of burden; but the African elephant was never utilized. These are not the conditions under which a whole race could be crushed into a process of degeneracy. 3. Comparison with other races shows the negro's inferiority. The Egyptian civilization was reared on the African Continent by the side of the barbarous negro, and under the same conditions. If the materials of civilization were introduced from Asia, it was certainly easier for the negro to introduce them from Egypt. America is not naturally superior in its physical conditions to Africa. Its only cereal is maize. Its principal edible roots are the mandioca and the potato; and the feeble llama and vicuna are the only native animals capable of domestication as beasts of burden. Yet the civilization of the Nahuatl nations of Mexico, the Quiches of Central America, the Mayas of Yucatan, and the Aymaras and Quichuas of Peru, had become, both in respect to intellectual and industrial advances, and judicial, moral, and religious conceptions, almost a stage of true enlightenment. The glaring fact of negro inferiority in respect to social conditions cannot be explained by any appeal to adverse conditions. Such are the ethnological facts and the coördinated circumstances. But in proof of my position I make another point: 4. The anatomical structure of the negro is inferior. The lean shanks, the prognathous profile, the long arms (which do not always exist), the black skin, the elongated and oblique pelvis—these are *all* characteristics in which, so far as the negro diverges from the white man, he approximates the African apes. The skull also is inferior in structure and in capacity, and in the relative expansion of its different regions. Among whites, the relative abundance of 'cross-heads' (having permanently unclosed the longitudinal and transverse suture on the top of the head) is one in seven; among Mongolians, it is one in thirteen; among negroes, it is one in fifty-two. This peculiarity is supposed by some to favor the prolonged development of the brain. In any event, it is most frequent in the highest races. Again, the prevailing form of the negro head is dolichocephalous; that of civilized races is mesocephalous and brachycephalous. That is, it lacks the breadth which we find associated with executive ability. The broadest negro skull does not reach the average of the Germans, nor does the best Australian skull, let me add, reach the average of the negro. Finally, the capacity of the negro cranium is inferior. Assuming 100 as the average capacity of the Australian skull, that of the negro is 111.6, and that of the Teuton 124.8. Now, no fact is better established than the general relation of intellect to weight of brain. Welker has shown that the brains of twenty-six men of high intellectual rank surpassed the average weight by fourteen per cent. Of course, quality of brain is an equally important factor; and hence not a few men with brains even below the average have distinguished themselves for scholarship. But this does not abolish the rule; nor does it prove that the racial inferiority of the negro brain, in respect to size, is not to be taken as an index of racial inferiority in respect to intelligence and the capacity for civilization; and this all the more, since the quality of the negro brain is also inferior.

"I am not responsible for the inferiority of the negro. I am responsible if I ignore the facts. I am culpable if I hold him to the same standard as the white man. My appeals to him must be of a widely-different character from my appeals to the Aryan Hindoo, or the Mongoloid American savage. The ethnological facts have their application in all missionary efforts."

Of the subsequent discussion on "Pri-

meval Man in Europe," and "The Antiquity of Man," we have no room to speak. Prof. Winchell deduces a general view, which harmonizes all the phases of evidence, and though contravening the old traditions, must be accepted in proportion as men esteem truth to be more desirable than error. He says:

"This scheme of prehistoric times, embracing only a few conjectural features, weaves in all the facts of history and science. If it traverses old opinions, we need not mourn. New truths are better than old errors. Fact is worth more than opinion. Certainty is more desirable than confidence. Progressive knowledge implies much unlearning. The loss of a belief, like the death of a friend, seems a bereavement: but a false belief is only an enemy in a friend's cloak. It is only truth which is divine; and, if we embrace an error, we shall not find it ratified in the oracles of divine truth. We who hold to the valid inspiration of the sacred records may feel assured that nothing will be found affirmed therein which collides with the final verdict of intelligence. Nor has the color of the first man any concern with a simple religious faith. If our creed embodies a dogma which enunciates what is really a conclusion, true or false, based on scientific evidence—that is, evidence brought to light by observation and research—that may be exscinded as an excrescence. All such subjects are to be settled by scientific investigation—not by councils of the Church. Ecclesiastical faith has had a sorry experience in the attempt to sanctify popular opinions. A faith that has had to surrender the geocentric theory and the denial of antipodes, and of the high geological antiquity of the world, should have learned to discriminate between religious faiths and scientific opinions. Religious faith is more enduring than granite. Scientific opinion is uncertain; it may endure like granite or vanish like a summer cloud. Religious faith is simple, pure, and incorruptible; scientific opinion is a compound of all things, corruptible and incorruptible. Let us not adulterate pure faith with corruptible science. An unadulterated faith can be defended by the stardiest blows of reason and logic; a corrupt faith puts reason and logic to shame."

PRINCIPLES AND PRACTICE OF TEACHING. By JAMES JOHONNOT. New York: D. Appleton & Co. Pp. 395. Price, $1.50.

As it is now the latest, so Prof. Johonnot's new work on education is undoubtedly the best manual of school guidance that has yet been prepared. It is better adapted to the present condition of educational progress than any other teachers' manual that we have yet seen. Two things have come prominently forward in the recent development of thought with reference to the work of instruction: 1. Science is gaining a more liberal recognition in our courses of study, and is more and more coming to be the chief thing; and, 2. Teachers are compelled to give more attention to psychological science as an indispensable prerequisite to the intelligent management of school-work. There is still need enough for advancement in both these directions, for there are plenty of schools that are hardly beyond the middle ages in their appreciation of science, and plenty of teachers who are as ignorant of the laws of mind as the untutored savage. But these considerations are surely though slowly emerging into confessed prominence, and are beginning to take that controlling position in the philosophy of education which is bound to be universally conceded to them in the not very distant future.

Prof. Johonnot is by no means a blind admirer of things established in our educational systems. He clearly sees that the whole subject is in movement, that in many respects current education is profoundly imperfect, that a critical spirit widely prevails in regard to it, and that there is plenty of work for reformers in bringing the general practice into harmony with principles that have been definitely worked out. He is not only a practical educator of large experience in the special work of training teachers, but he has his independent views of what is needed, and how to attain it; and his work will accordingly be found fresh, suggestive, and stimulating, to all teachers and school officials who are devoted to organizing and carrying out the best plans of instruction. That he has reached anything like a finality in the policy of school management he would be the last to claim; but we must cordially concede to him the merit of having grasped the problem of practical culture in its latest exigencies and newest developments. In a growing and unfolding subject, methods must be tentative and proximate: it is enough if they are better than their predecessors. Prof. Johonnot has well digested for us the latest theoretical wisdom regarding the principles of teaching, and he has embodied these in an improved system of practice, which has stood the test of experience. Having unfolded the general principles of culture in the earlier and chief portions of his work, the author devotes the last hundred pages to

laying down courses of study, general and special. This is the constructive part, which is ever the most difficult and liable to criticism, because of its conflict with preëxisting habits; but there can be no doubt that this portion of his volume involves a marked advance on previous practice. We have seen no popular scheme of study in which Nature is so confessedly the groundwork on which the whole fabric of mental cultivation is to rest, and in which science is so intimately interwoven with the constant course of school-work. Hitherto, scientific studies have been too much looked upon as secondary, intrusive, and to be superinduced upon a preëstablished scheme; they are here made the starting-point, and incorporated in the plan of studies as an essential and fundamental element. In thus contributing to the better organization of school exercises, this book meets an urgent need of the times which cannot fail to be appreciated by many teachers.

THE PSYCHO-PHYSIOLOGICAL SCIENCES AND THEIR ASSAILANTS: Being a Response by ALFRED R. WALLACE, of England; Prof. J. R. BUCHANAN, of New York; DARIUS LYMAN, of Washington; EPES SARGENT, of Boston, to the Attacks of Prof. W. B. CARPENTER, of England, and Others. Boston: Colby & Rich. Pp. 216.

THIS is the counterblast of the spiritualists against the lectures of Dr. Carpenter on spiritualism, mesmerism, etc. For three hundred years the devotees of scientific knowledge have been laboring to disentangle the natural from the supernatural, which had previously been so mixed up in the traditions of learning that "Nature," as a system of uniform and verifiable laws, was unknown. The progress of science has, in fact, consisted simply in tracing out and giving expression to these regularities and uniformities of the natural world. The spiritualists go back on all this, and declare it to be a false process and a spurious progress. They claim that the supernatural is to be included in the natural, and aver that they can investigate it and work out its laws so that they shall be a part of proper and legitimate science. They maintain, indeed, that they have already done this; but the difficulty is, that the whole scientific world denies it. Nor is there the slightest prospect that they will be able to convince scientific men of the validity of their claims on the basis of anything as yet accomplished. What they may do in the future we shall not presume to say; but we think they will have to be content to go on working out such results as they find possible, and trusting to time for that recognition which they so vehemently demand shall be accorded to them now. They make much complaint of the inhospitality of the scientific mind to what they call new truth, and this complaint we consider as wholly groundless. Prejudices, no doubt, arise from intense preoccupation in special lines of scientific labor, so that the physicist, for example, fails in appreciation of the biologist, while the chemist is indifferent to the work of the sociologist; yet in these diverse and widely-separated departments there is still sufficient liberality of spirit to leave all investigators unmolested in their special work. Why should the spiritualists wax wroth and imprecate Science and scientific men, because they will not drop their own researches and come over to help exploit the wonders of the preternatural sphere? If they cannot appreciate such marvelous things, why not leave them with due commiseration to wriggle and squirm in their congenial materialistic mud? Let the spiritualists go on and get out something worthy of attention, and it will be sure to get attention in due time.

THE NATIVE FLOWERS AND FERNS OF THE UNITED STATES, IN THEIR BOTANICAL, HORTICULTURAL, AND POPULAR ASPECTS. By THOMAS MEEHAN, Professor of Vegetable Physiology to the Pennsylvania State Board of Agriculture, Editor of the *Gardener's Monthly*, etc. Illustrated by Chromo-lithographs. Boston: L. Prang & Co. Pp. 16. Fifty cents per number.

BOTANICAL works with good colored illustrations have hitherto been far too expensive for general use; but the perfection now attained in the art of chromo-lithography makes possible a new departure in pictorial botany. The series now projected, the first two numbers of which are before us, show that a very considerable degree of fidelity and naturalness in the representation of flowers is already secured by the chromo-lithographic process, and we

may safely assume, from the skill and enterprise of the publishers, that they will attain still greater perfection as the work proceeds. Its editorial management is in the very best hands. Mr. Meehan is the conductor of the principal garden magazine of the country; and his thorough familiarity with botany, and his long practical acquaintance with horticulture, qualify him in a peculiar manner for the management of such an enterprise as this. The work will, therefore, combine great beauty of execution in the colored illustrations with a careful, trustworthy, and judicious text. Accompanying each plate there is a brief technical description, and three or four pages of general information in regard to the plant in question, its genus, geographical distribution, and mode of growth. The work is not offered as a complete illustrated flora of North America, the extent and expense of which would put it beyond popular reach, and prolong its publication for many years. Its scope is therefore limited to a selection of the most beautiful and interesting native flowers and ferns of the United States, preference being given to those most worthy of cultivation and available for garden decoration. After speaking of the difficulty of preparing a thoroughly systematic scientific work on the American flora, the editor remarks:

"It must not be inferred from this, however, that the present work is absolutely without system. It will be seen that the selection made for these two volumes covers a wide range of country, and offers a number of representatives of leading genera, chosen with reference to their various habits and to different geographical centres. These volumes are therefore absolutely complete in themselves, and may be said to give a good general idea of the floral wealth of our country. Those who are satisfied with the knowledge thus obtained may rest here. But it is hoped that the more enthusiastic lovers of flowers will welcome the succeeding volumes, which it is proposed to publish after the conclusion of this series. Each of the following series is also to consist of two volumes, and to form a complete whole by itself."

In the preparation of the work Mr. Meehan has had the important advantage of freely using the unrivaled facilities of the botanical garden at Cambridge, which he cordially acknowledges, as also the assistance kindly given him by various eminent botanists. The work is elegant, attractive, and meritorious, and we think it is certain to have a large patronage.

EXPERIMENTAL SCIENCE SERIES FOR BEGINNERS. II. SOUND: A Series of Simple, Entertaining, and Inexpensive Experiments in the Phenomena of Sound, for the Use of Students of Every Age. By ALFRED MARSHALL MAYER, Professor of Physics in the Stevens Institute of Technology. New York: D. Appleton & Co. Pp. 181.

THE second volume of this admirable series of books is now published, and its author is to be congratulated for more than fulfilling the promise of the opening volume. No less than one hundred and thirty experiments in sound are given, all of which are original in the simplified means by which the effects are produced. They, moreover, cover the whole ground of acoustics in so complete a manner that the pupil who goes through the volume, making all the experiments, will get an actual and living knowledge of the science, such as he can never acquire by reading any number of larger works. A list of apparatus to be used in the experiments on sound is given at the close of the volume, and can be purchased complete at the cost of $27.50. But, as Prof. Mayer remarks in the preface, "the student may find it cheaper to hunt up the materials, and then make his own apparatus; but so many have desired to have the sets ready for use, that I have complied with their request. Of course, it will be understood that the instrument-maker must be paid for the time taken in finding the objects in the market, and for the labor and skill spent in making the apparatus, and in packing it in convenient boxes."

MATTER AND MOTION. By J. CLERK MAXWELL, M. A., LL. D. New York: D. Van Nostrand. Pp. 224.

THIS monograph, by the eminent physicist and professor of Cambridge, is one of the best things that have yet appeared in Van Nostrand's "Science Series." Like everything from Clerk MAXWELL, it is clear, and, although the general treatment of dynamics is mathematical, there are many valuable definitions and much information in the book that will be available for the general reader

COMPARATIVE PSYCHOLOGY; OR, THE GROWTH AND GRADES OF INTELLIGENCE. By JOHN BASCOM. New York: G. P. Putnam's Sons. Pp. 291. Price, $1.50.

THIS small but thoughtful volume deserves to be very cordially commended to the students of psychological science. Though a controversial work, it is free from narrowness and the usual effects of partisan discussion, and it is written by a thinker who can appreciate views with which he disagrees, and freely acknowledges his indebtedness to the party with which he is, nevertheless, at radical issue. Of the two great schools of philosophy, the intuitional and the empirical, one holding that mental faculties are immediate *a priori* gifts to intelligent creatures, and the other that they are results of development through experience, the author of this volume holds with the first; but he acknowledges that it has been written to elucidate problems and carry out inquiries "that would hardly have been suggested but for the empirical philosophy." The object of the book is admirably stated in the following extract from the author's preface:

"The advocates of the empirical philosophy are wont to criticise the intuitional philosophy in two respects: first, as overlooking the relation between the mature mind and the mind of the infant—between rudimentary and developed powers; and, second, as overlooking the still more important connection between the intelligence of to-day and that of remote previous periods, between the intelligence of man and that of animals, and of the earlier human life from which it has been derived. We grant these points to be well taken, especially the latter. Without tracing the history of intelligence, we are not prepared to decide what is primitive and what is acquired; what is original material and what is the deposit of growth. The empiricist cannot be fully and fairly met without traveling with him these spaces of evolution, and determining at least their general facts and laws. This I have undertaken in the present volume. It is my purpose to test the nature and extent of the modifications put upon human psychology by its relations in growth to the life below it; and, in doing this, to reach a general statement of each stage of development."

A philosophical writer of our time could hardly occupy himself with a more pertinent problem than is here presented. It has been the reproach of the *a priori* method that it has ignored the subject of mind in its lower or comparative manifestations. It has neither worked from the base of fundamental organic conditions, nor has it systematically recognized them, and for this reason the method was probably losing its hold upon the scientific mind of the period. Clearly aware of this deficiency, Dr. Bascom has addressed himself to the task of supplying it, and his book will do much to rescue the subject from the reproach into which it had fallen.

WISCONSIN GEOLOGICAL SURVEY. Report for 1877. By J. C. CHAMBERLIN, Chief Geologist. Madison: Atwood print. Pp. 95.

THE survey of Wisconsin is now completed, and the results will soon be in readiness for publication. The final report will form three volumes, with maps, of which one volume, with atlas, has already appeared. During the season of 1877, eleven surveying parties were in the field. The survey suffered a serious loss by the accidental death of Mr. Moses Strong, an enthusiastic young mining engineer, of brilliant attainments, who lost his life by the capsizing of his canoe while ascending the rapids of the Flambeau River.

STATE REGULATION OF VICE: REGULATION EFFORTS IN AMERICA. THE GENEVA CONGRESS. By AARON M. POWELL. New York: Wood & Holbrook. Pp. 127. Price, $1.

MR. POWELL does not believe in the state regulation of vice, and gives his reasons in this book. The subject is considered from the point of view of the philanthropist and reformer, rather than from that of social science.

MINERALOGY. By J. H. COLLINS, F. G. S. With 579 Illustrations. New York: G. P. Putnam's Sons. Pp. 206. Price, $1.50.

THIS little manual is remarkable for the profuseness and neatness of its crystallographic illustrations. It is designed for practical working miners, quarrymen, field-geologists, and the students of the science classes in connection with the department of science and art in England.

GEOGRAPHICAL SURVEYS WEST OF THE 100TH MERIDIAN, IN CHARGE OF LIEUTENANT G. M. WHEELER, ENGINEER U. S. ARMY. Part II., Vol. IV. Paleontology. Letter-press, pp. 365, with 83 Plates. Washington: Government Printing-Office.

THE present installment of Lieutenant Wheeler's Report consists of a memoir, by

E. D. Cope, on extinct vertebrata from New Mexico. The fossils here described and determined represent four geological periods, in basins that had not previously been explored, viz., the Trias, the Eocene, the Loup-Fork Epoch, and the Postpliocene of the Sandia Mountains. The first vertebrate fossils ever determined from the Trias of the Rocky Mountains are included in this memoir. Of the high intrinsic value of Prof. Cope's work there is no need for us to say anything: his memoirs on the paleontology of our Western Territories are authoritative documents throughout the world of science. But we cannot refrain from commending the truly admirable lithographic plates by which the text is illustrated and adorned.

THE FUTURE OF SANITARY SCIENCE. An Address before the Sanitary Institute of Great Britain. By B. W. RICHARDSON, M. D. Macmillan & Co. Pp. 47. Price, 25 cents.

DR. RICHARDSON has become the prophet of our sanitary future, and discourses of its prospects in this pamphlet in his peculiar style. He does not fail to magnify his calling, and presents its claims in a quite extraordinary way, saying: "All political troubles have a physiological cause. To the statesman not less than to the physician, physiology is the only true source of knowledge. A society such as ours, therefore, possessing as it does professed physiological skill, may render most important service by tracing out for the legislator the simplest scientific means for removing atmospheric impurities, and by preparing for that sanitary future when men universally shall breathe purity even with their freedom."

CEREBRAL HYPERÆMIA: THE RESULT OF MENTAL STRAIN OR EMOTIONAL DISTURBANCE. By WILLIAM A. HAMMOND, M. D. New York: G. P. Putnam's Sons. Pp. 108. Price, $1.

THIS is a very important little monograph by an eminent medical authority, who has had large special experience in all that pertains to morbid conditions of the brain. The reason for and character of his little book are thus well represented by the author in his preface:

"The disease which is considered in the ensuing pages is more common, according to my experience, than any other affection of the nervous system. It is especially an outgrowth of our civilization, and of that restless spirit of enterprise and struggle for wealth so characteristic of the American people. It is an easily preventable disorder, not for this purpose requiring extensive hygienic operations, but simply the acts of the individual in using his or her brain with the same regard for its well-being as is ordinarily extended by the humane carter to the muscular system of his horse. The brain of man is strong: it will endure a terrible amount of illusage; but there are limits to the abuse which may be inflicted upon it with impunity, and few there be who do not pass them.

"It is, perhaps, too much to expect the emotions to be entirely under the control of the individual, nor is it desirable that we should be reduced to the condition of intellectual automata, moved always by reason and judgment, and never by feeling. But it is entirely within the power of every one, by that self-discipline so seemly in all, to obtain such a degree of mastery over unworthy or excessive passions as will prevent them dominating over the whole mind and body, to the detriment of both.

"Ill-regulated emotions are even more prolific of brain-disorders than severe mental labor, and many a person considered to be suffering from what is called nervous prostration or exhaustion is simply the subject of emotional disturbance and a consequent condition of cerebral hyperæmia."

FIRST PRINCIPLES OF AGRICULTURE. By HENRY TANNER, F. C. S. New York: Macmillan & Co. Pp. 95.

THIS is a very good little summary of elementary scientific facts and principles relating to agriculture. The difficulty about it is that it is too small—a mere primer; but those who want an introduction to the subject, to be followed by the use of larger works, will find it serviceable. Scientific agriculture, from the complexity of all its problems and the obscurity of many of them, requires to be studied with some thoroughness, in fact to be mastered, before it can be made practically and safely available.

A DICTIONARY OF MUSIC AND MUSICIANS. Edited by GEORGE GROVE, D. C. L. Vol. I., Part II. New York: Macmillan & Co. Pp. 127. Price, $1.25.

THE second number of this elaborate work is now ready, and its topics range from Ballad to Boïeldieu. Its character is well sustained, and the admirable sketch of Beethoven, with the analysis of his music, is alone worth the price of the work.

PUBLICATIONS RECEIVED.

Elements of Dynamic. Part I. Kinematic. By W. K. Clifford. London and New York: Macmillan. Pp. 230. $2.50.

The Speaking Telephone, Talking Phonograph, and other Novelties. By G. P. Prescott. New York: D. Appleton & Co. Pp. 431. $3.

Physics of the Infectious Diseases. By Dr. C. A. Logan. Chicago: Jansen, McClurg & Co. Pp. 212. $1.50.

A Course in Arithmetic. By F. W. Bardwell. New York: Putnams. Pp. 166.

Physical Technics. By Dr. J. Frick. Philadelphia: Lippincott. Pp. 467. $2.50.

Visions: A Study of False Sight. By Dr. E. H. Clark. Boston: Houghton, Osgood & Co. Pp. 333. $1.50.

Report on Forestry. By F. B. Hough. Washington: Government Printing-Office. Pp. 650.

Manual of the Apiary. By Prof. A. J. Cook. Chicago: T. G. Newman & Son. Pp. 286. Paper, $1 cloth, $1.25.

Annual Record of Science and Industry. By S. F. Baird. New York: Harpers. Pp. 494. $2.

The Ethics of Positivism. By G. Barzellotti. New York: Somerby. Pp. 327. $2.

Ferns of Kentucky. By J. Williamson. Louisville: J. P. Morton & Co. Pp. 154. $2.

Sequel to "Essays." By C. E. Townsend. New York: Somerby. Pp. 102.

Practical Chemistry for Medical Students. By M. M. P. Muir. London and New York: Macmillan. Pp. 64. 60 cents.

Report of the Ohio Commissioner of Common Schools. Columbus: Nevins & Myers print. Pp. 384.

Report of the Wisconsin Board of Health. Madison: Atwood print. Pp. 200.

The Railway in its Relation to Public and Private Interests. By Simon Sterne. New York: Press of the Chamber of Commerce. Pp. 38.

Chronic Aural Discharges. By Dr. J. J. Chisholm. Reprint from the *North Carolina Medical Journal*. Pp. 10.

Facial Neuralgia. By Dr. J. Martine Kershaw. St. Louis: Schroback & Co. print. Pp. 66.

The Hessian Fly. By Prof. A. J. Cook. Pp. 14.

Uniform Non-Local Time. By S. Fleming. Ottawa, Can.: The Author. Pp. 32.

Deep-Sea Soundings. By Lieutenant-Commander J. F. Jewell, U. S. N. Claremont, N. H.: Claremont Manufacturing Co. print. Pp. 63.

Report of the Executive Board of the Rochester City Board of Health. Rochester, N. Y.: *Democrat and Chronicle* print. Pp. 27.

Metric Weights and Measures for Medical Purposes. Washington: Government Printing-Office. Pp. 40.

Opinion of the Ohio Attorney-General on the Powers of Boards of Education. Columbus: Nevins & Myers. Pp. 24.

Quarterly Report of the Chief of the Bureau of Statistics. Washington: Government Printing-Office. Pp. 126.

Certain Symptoms of Nervous Exhaustion. By Dr. G. M. Beard. Reprint from the *Virginia Medical Monthly*. Pp. 24.

The Army of the Republic. By Henry Ward Beecher. New York: *Christian Union* print. Pp. 23. 10 cents.

How to spend the Summer. New York: *Christian Union* print. Pp. 105. 25 cents.

The Law of Population. By A. Besant. New York: A. K. Butts. Pp. 47.

POPULAR MISCELLANY.

Archæological Researches in the Great American Bottom.—The alluvial plain known as the "Great American Bottom," lying on the east side of the Mississippi, in Illinois, between Alton on the north and Chester on the south, and having an average width of eight or nine miles, is a region of wonderful fertility now, and the remains of ancient occupation there abundantly found prove that the mound-builders were not blind to the agricultural value of this remarkable tract. It was indeed "one of their greatest seats of empire," in the language of Mr. H. R. Howland, who has published, in the Bulletin of the Buffalo Society of Natural Sciences, an account of certain notable archæological researches made in the "American Bottom." The mounds in this tract seem to have been divided into three principal groups: one lying within the limits of East St. Louis; another on the banks of Long Lake, twelve miles northward; and the third—one of the most extraordinary groups in this country—between Indian Lake and Cahokia Creek, some six miles from the Mississippi, and eight miles to the northeast of East St. Louis. In this last group is the great Cahokia Mound, by far the most important monument left by the mound-builders. The several groups are connected by lines of mounds at irregular intervals, and the total number is at least two hundred. Some two or three years ago Mr. Howland, having learned that one of the mounds in the second group was being removed to procure material for road-making, repaired to the spot and found the work of destruction already well advanced. In the mean time some interesting discoveries had been made. At the height of four or five feet above the base of the mound the workmen came upon a considerable deposit of human bones, and on the same level were discovered a number of valuable relics, many of them wrapped in a sort of matting. This was made of a coarse, cane-like fibre, simply woven without twisting, the flat strands measuring about one-eighth inch in

width. Among the articles found were several tortoise-shells of beaten copper. One of these was about one sixty-fourth of an inch thick, two and one-eighth inches long, and thirteen-sixteenths of an inch in height; this was the largest one of three in the author's possession. Their shape is remarkably true, the workmanship evincing delicate skill. Each tortoise-shell appears to have been originally covered with several wrappings, first a woven cloth of vegetable fibre, then a softer, finer fabric of rabbit's hair apparently, next a membranaceous coating, finally a layer of non-striated muscular fibre—possibly intestine or bladder. Besides these singular objects are two specimens of the lower jaw of the deer, the part which contains the teeth being incased in a thin covering of copper, and the whole wrapped in the same manner as the tortoise-shells. Other relics found in the same mound—specimens of handicraft, sea-shells from the Gulf of Mexico, etc.—give evidence of the high grade of technical skill and the far-reaching intercourse of the prehistoric people who, in the long forgotten past, inhabited the Great American Bottom.

Age of the Ohio "Forest-Beds."—The "forest-bed" of the Ohio geological formation is a "layer of carbonaceous matter, with logs and stumps, and sometimes upright trees." It everywhere rests upon true glacial drift, and in it are found remains of mammoth, mastodon, and their contemporaries. The deposit overlying this "forest-bed" in Ohio is, by Dr. Newberry, described as lacustrine drift, but Mr. W. J. McGee, in the *American Journal of Science*, shows that in Northeastern Iowa this same "forest-bed" is overlaid by *true glacial drift*, and therefore that it must be of interglacial age. In the region just named the uppermost deposit, overlying the "forest-bed," is beyond the shadow of a doubt glacial drift very slightly or not at all modified, and exhibiting no distinct stratification. The only difference between the upper and lower parts is that the lower part contains a larger proportion of gravel and worn bowlders from the immediate vicinity. The upper part contains no bowlders, indeed, except those of granite, syenite, quartzite, and other metamorphic rocks from far to the northward. These, however, are quite abundant. In some fields it has been necessary to remove dozens of bowlders of one hundred pounds' weight and upward from each acre before the land could be ploughed. Some also are quite large, reaching scores of tons in weight. Glacier-marked bowlders are rare, however. Perhaps one in a thousand shows plainly grooves and deep scorings; but many others are less distinctly marked. Still not more than one-tenth exhibit any other marks of glacial action than a rounded form.

Medico-Psychological Rubbish.—Dr. Maudsley's *Journal of Medical Science* quotes the following passage from the *British Medical Journal* as an example of the rubbish that passes current in medico-psychological matters: "One of the most curious facts connected with madness is the utter absence of tears amid the insane. Whatever the form of madness, tears are conspicuous by their absence, as much in the depression of melancholia or the excitement of mania as in the utter apathy of dementia. If a patient in a lunatic asylum be discovered in tears, it will be found that it is either a patient commencing to recover, or an emotional outbreak in an epileptic who is scarcely truly insane; while actually insane patients appear to have lost the power of weeping; it is only returning reason which can once more unloose the fountains of their tears. Even when a lunatic is telling one in fervid language how she has been deprived of her children, or the outrages that have been perpetrated on herself, her eye is never even moist. The ready gush of tears which accompanies the plaint of the sane woman contrasts with the dry-eyed appeal of the lunatic. It would indeed seem that tears give relief to feelings which, when pent up, lead to madness. It is one of the privileges of reason to be able to weep. Amid all the misery of the insane, they can find no relief in tears."

The Devil and the Oak-Trees.—A legend current among the peasants of Unterinnthal (Tyrol) accounts as follows for the sinuous outline of oak-leaves (we translate the legend from *Die Natur*): The wicked old fiend one day would tempt the good God, and so asked

if he would grant him a trifling request. With a smile, the Lord answered, "What you ask will be granted so soon as the oaks have lost all their leaves." The *Gottsei beiuns* (literally, "God-be-with-us"—in old times people did not like to name the devil, lest he should appear) was delighted, and eagerly longed for the coming of autumn; but the oak-leaf gave no sign of falling. So the devil, somewhat disappointed, deferred his hope to winter. Winter came, but still the leaves clung fast to the oaks, though they rustled all yellow and brown in the wind. Satan had then to comfort himself with the thought that at least they would fall in the spring. But when joyous Spring came, making its progress through the verdant fields, first young leaves began to sprout, and not until these had grown to considerable size did the old ones drop off. Then the prince of darkness knew that his request would never be granted, for the oak never loses *all* its leaves at once. So in his rage he rushed howling and roaring at the oak-trees, and with his claws tore the leaves to pieces, and we, to this day, only see the shreds.

A Big Fish-Worm.—The people who inhabit the highlands of Southern Brazil have a firm belief in the existence of a gigantic earthworm fifty yards or more in length, five in breadth, covered with bones as with a coat-of-mail, and of such strength as to be able to uproot great pine-trees as though they were blades of grass, and to throw up such quantities of clay in making its way underground as to dam up streams and divert them into new courses. This redoubtable monster is known as the "Minhocao." Dr. Fritz Müller, who has for some years resided in Brazil, studying in particular the entomology of that country, has thought it worth his while seriously to investigate the grounds of this popular belief, and has published the result of his researches in a German periodical, from which *Nature* has taken the gist of his communication. As will be seen, he is inclined to admit, with considerable allowance, the truth of the popular stories. The evidence of the existence of the Minhocao is of this kind: About eight years ago one of these monsters made its appearance in the neighborhood of Lages, but perhaps it will be safer to say that it "is reported to have made its appearance." One Francisco de Amaral Varello, at a place distant ten kilometres from that town, saw, lying on the bank of the Rio das Caveiras, an animal nearly one metre in thickness, not very long, and with a snout like a pig. He went to call his neighbors, but when he returned to the rescue the animal had disappeared, and the party saw only the trench it had made in disappearing under the earth. A week later a similar trench was seen at the distance of some six kilometres from the former one. One F. Kelling, a German, from whom Dr. Müller got this information, was at the time a merchant at Lages, and he saw these trenches. Another German, E. Odebrecht, while surveying a line of road from Itajahy into the highlands of Santa Caterina several years ago, crossed a broad, marshy plain traversed by an arm of the Marombas River, where his progress was much impeded by "devious winding trenches which followed the course of the stream, and occasionally lost themselves in it." These trenches he is now inclined to believe to be the work of the Minhocao. Other testimony, relating to five or six earlier apparitions of the Minhocao, is cited, but we have no room to give it here. To Dr. Müller the conclusion appears inevitable that in the above-named region of Brazil "long trenches are met with, which are undoubtedly the work of some living animal. It might be suspected," he adds, "to be a gigantic fish allied to *Lepidosiren* and *Ceratodus*; 'the swine's snout' would show some resemblance to *Ceratodus*, while the other characters show rather an analogy to *Lepidosiren*. In any case," he concludes "it would be worth while to make further investigations about the Minhocao, and, if possible, to capture it for a zoölogical garden."

Aurora Borealis.—From statistics of the aurora borealis collected by H. Fritz, and extending from 1846 to the present year, we learn that out of 2,035 days in the months from August to April, on which auroras were seen, 1,107 were aurora-days in Finland, and that of these 1,107 auroras 794 were simultaneously visible in Europe and America, 101 only in Europe, and 212 were visible only in Finland. During the same period

and within the same months, 928 auroras were seen in Europe or America which were invisible in Finland. These statistics further serve to show the geographical distribution of auroras, which is as follows: The zone of greatest frequency and intensity begins near Barrow Point (latitude 72° north), on the northern coast of America; thence it passes across the Great Bear Lake toward Hudson Bay, which it crosses at latitude 60° north, passing over Nain on the coast of Labrador, keeping south of Cape Farewell. Its further course is between Iceland and the Faroe Isles, to the vicinity of North Cape in Norway, and thence into the Arctic Sea. Thence it probably passes round Nova Zembla and Cape Isheljuskin, approaches the north coast of Asia in the eastern part of Siberia, in the longitude of Nizhni Kolymsk, and thence returns to Barrow Point.

Analogies of Plant and Animal Life.—Some very interesting analogies of plant and animal life are pointed out by Mr. Francis Darwin in a recent lecture. In the first stage of individual existence—the egg or the germ—the analogy is perfect; it is no less so in the stage just succeeding. Among animals there are great differences as to the degree of development attained by the young ones before they enter the world. For instance, a young kangaroo is born in a comparatively early stage of development, and is merely capable of passive existence in its mother's pouch, while a young calf or lamb soon leads an active existence. Or compare a human child, which passes through so prolonged a condition of helplessness, with a young chicken, which runs about and picks up grain as soon as it quits the shell. As analogous cases among plants Mr. Darwin cites the mangrove and the tobacco-plant. The ripe seed of the mangrove is not scattered about, but remains attached to the capsule still hanging on the mother-plant. In this state the seeds germinate and the roots grow out and down to the sea-level, and the plant is not deserted by its mother until it has got well established in the mud. For the conditions of life against which the young mangrove has to make a start are unfavorable enough. The most intrepid seedling might well cling to its parent on finding that it was expected to germinate in soft mud daily flooded by the tide. Perhaps, adds the author, the same excuse may be offered for the helplessness of babies—the more complicated the conditions of life, the greater dependence must there be of offspring on parent. Compare a young tobacco-plant with a young mangrove. All the help the seedling tobacco receives from its parent is a very small supply of food. This it uses up in forming its first pair of leaves, and it has then nothing left by way of reserve, but must depend on its own exertions for subsistence—that is to say, it must itself manufacture starch (which is the great article of food required by plants) from the carbonic acid in the air. In this respect it is like a caterpillar which is formed from the contents of the egg, but has to get its own living as soon as it is born.

The Construction and Erection of Lightning-Rods.—Dr. R. J. Mann lately summed up in a series of aphorisms the fundamental conditions to be observed in the construction of lightning-rods. We have not room here for the whole series, but select a few of the most important. The main stem of a *copper* lightning-conductor should never be less than $\frac{1}{10}$ of an inch diameter; this dimension is not sufficient for a building more than eighty feet high. Galvanized iron may be used instead of copper, but then the diameter must be greater in the ratio of 6.7 to 2.5, the conducting capacity of iron being to that of copper as 14 to 77. A galvanized iron-rope conductor should never be less than $\frac{1}{7}$ of an inch diameter; a galvanized iron strip should be 4 inches wide and $\frac{1}{4}$ of an inch thick. A lightning-rod must be continuous and unbroken from end to end. A rod need not be attached to a building by insulated fastenings; metal clamps may be safely employed, provided the rod be of good conducting capacity and otherwise efficient. Above, the rod must terminate in metal points, well projected into the air; these points should be multiple and perfectly sharp. The bottom of the conductor must be carried down into the earth and be connected with it by a surface-contact of large extent. All large masses of metal in a building should be metallically connected with the lightning-rod, except when they

are liable to be occupied by people during a thunder-storm—an iron balcony, for instance. In such cases it is better not to have the iron connected with the conductor, for there is some risk of persons standing on the balcony furnishing a path for the lightning to the rod.

North American Archæology.—The directors of the Smithsonian Institution contemplate the publication of an exhaustive work on the antiquities of North America, and earnestly invite the coöperation of archæologists and of all who may be possessed of information concerning the aboriginal history of North America. The ancient monuments to be described in the work are mounds and earthworks, shell-heaps, cave and cliff dwellings, masonry, sculptured slabs or carved images, inscriptions, and rock-paintings, graves and cemeteries, aboriginal quarries, and salt-works, *caches* or deposits of objects in large quantities, workshops or places of ancient aboriginal industry, ancient roads or trails, reservoirs and aqueducts. In addition to original records and descriptions of the objects here enumerated, the Smithsonian Institution desires to obtain copies of all books, memoirs, pamphlets, extracts from periodicals, and newspaper clippings, having any relation whatever to American archæology. Information is further solicited concerning all collections of American antiquities, *however small*, whether in private hands or in public museums. Any one can obtain, on application to the Smithsonian Institution, its "Circular in Reference to American Archæology," in which are stated in detail the different subjects concerning which specific information is wanted.

A New Fact in Natural History.—In the books of Leviticus and Deuteronomy it is forbidden to eat any creature living in the waters that "hath not fins and scales." Of such animals it is written: "They shall be an abomination unto you; ye shall not eat of their flesh, but ye shall have their carcasses in abomination." Christians, at least modern Christians, are not wont to hold oysters as "unclean" and "an abomination," notwithstanding the very high authority on which they are so declared to be in the Holy Scriptures. But the Jew still obeys the divine command, as of old; hence the devout Hebrew knows nothing, from personal observation, of the delicate flavor of the oyster, and no doubt that savory bivalve has oftentimes been a stumbling-block and a scandal for the weaker ones of the children of Israel. But a truly wonderful discovery has been made by a learned rabbi in England, which takes the oyster out of the class of things forbidden, and makes it as harmless to the conscience as, doubtless, it will be grateful to the palate of the Jew. This rabbi has read Mr. Darwin's works, and read them to some purpose, for he finds that, "in consequence of the theories" of that famous naturalist, "oysters are plants, and may therefore be eaten by Jews." We hasten to add that as yet the rabbi's views are merely matters of private opinion, and hence no safe guide for consciences; but a grand council will before long be summoned to render authoritative judgment in the matter. Its decision will be awaited with no little interest. It is to be hoped that the vegetable side will prevail. One strong argument in its favor is the notorious fact that oysters are *planted*, the result of course being the *oyster-plant*.

Peculiarities of Vision.—Mr. Galton, in his paper on "Composite Portraits" (*see* page 465 of this number), observes that "the two separate impressions received by the brain through the stereoscope do not seem to be relatively constant in their vividness, but sometimes *the image seen by the left eye prevails over that seen by the right, and vice versa*." This remark has elicited from a correspondent of *Nature* a communication in which he describes a very curious defect in his own eyesight. This correspondent's right eye is fairly long-sighted, but the left eye is short-sighted. Print which is read distinctly by the one at the distance of eighteen inches, cannot be easily read by the other at a distance of over eight and a quarter inches. The result of this is, that the right—the long-sighted eye—closes involuntarily when he reads. Again, when he looks intently at a distant view, the left or short-sighted eye shuts occasionally. When both eyes are open he has two sep-

arate images presented to the brain, one blurred and indistinct, even for faces a yard distant, and the other clearly defined for objects at ordinary distances. "How is it," he asks, "that my brain or mind rejects the blurred image, and chooses the distinct one? . . . . If I get a particle of dust in the good eye, or close it, I immediately see the blurred image. . . . This blurred image always appears at a higher level than the other. Things appear as a rule," he adds, "much flatter to me than to people who enjoy binocular vision. I know this because I have a pair of spectacles so arranged as to equalize my sight. When I put them on, objects like trees put on a delightful fullness and roundness to which I am usually quite a stranger. I may add that two of my brothers have a similar defect of vision."

The Cactus as a Lava-Breaker.—A citation, in the bulletin of the Torrey Botanical Club, from Dr. Peters, the famous asteroid-hunter, gives an interesting fact in relation to the doctor's earlier days, when he ate prickly pears, or the fruit of the Indian-fig cactus, on the sides of Mount Etna. He describes the lava-beds as covered with impenetrable patches of *Opuntia ficus Indica*, the Indian fig-cactus. These patches are the result of economic planting, with the intention of producing soil on the lava-beds. The Sicilian throws down a handful of soil, then drops upon this a bit of the cactus, which immediately roots. The effect of this cactus-growth is to facilitate the weathering of the rock, and thus make soil. The next step, after clearing off the cactus, is to plant fig-trees. In this way the lava-beds of Mount Etna are transformed into fruitful gardens.

A New Septic Organism.—Mr. Dallinger lately gave, before the London Royal Society, an interesting account of the life-history of a peculiar microscopic organism discovered by him in certain decomposing fluids. This organism never exceeds the $\frac{1}{1000}$ of an inch in long diameter; in shape it is oval; at its anterior extremity it has a head-like protrusion bearing a delicate flagellum. From the sides of the shorter or front segment of the oval project two long flagella, and these, as a rule, trail behind, one on each side. It swims rapidly, but has also the capacity of anchoring both of its lateral flagella to the floor of the microscope-stage, or to a decomposing mass in the drop of liquid in which it is examined under the microscope. By steadily observing it in the free-swimming condition, it may be seen to undergo self-division, the division beginning in the front flagellum, and proceeding until, by longitudinal fissure, a new lateral flagellum is made for each half. There are now two perfect organisms. The author confined his attention for some time continuously to one of the segmental portions, and succeeded in tracing the process to its ultimate results. Having so observed a number of the self-dividing organisms, he found that in the majority of cases, when the process of fissure ceased, there was simultaneous exhaustion of vital action, and death; but in a certain proportion of cases, in which fissure was not so long continued, there was a change to the amœboid condition, the lateral flagella being absorbed, and the body becoming oval with anterior flagellum only. It now swims easily, but only in a straight line. It soon comes in contact with a colony of the organism in the perfectly flagellate condition, attaches itself to one of them, which soon unanchors, and both swim away. In course of time their movements become sluggish; the sarcode of their bodies is palpably blending, they become quite still, except for amœboid movements, and then become one oval mass. After three or four hours this pours out minute specks, which appear to develop into the adult form and size. The temperature of 142° Fahr. is fatal to the perfect organism; the "speck," germ, or spore, can bear with impunity a temperature of 250° Fahr.

NOTES.

THE schooner Eothen, carrying the expedition to search for the relics of Sir John Franklin's party, sailed from New York on Wednesday, June 19th, under the command of Captain Thomas F. Barry, whose discovery of spoons bearing Sir John's crest, in the hands of an Esquimaux tribe, was the occasion of fitting out this expedition. Lieutenant Schwatka, Third U. S. Cavalry, will command the search-party, and will have for guide and interpreter Joseph Eberbing, "Esquimaux Joe" of Polaris fame. The

Eothen will touch first at Whale Point, in Hudson Bay, and there recruit a force of Esquimaux to reënforce the search-party; from Whale Point the schooner will proceed to Beach Point, Repulse Bay, one hundred and forty miles north. Thence the search-party will proceed inland by sleds five or six hundred miles to a point in the northern portion of Boothia Felix, where the last survivors of the Erebus and Terror crews are said to have perished, and where, according to the natives, their bodies are buried.

REDISCOVERY of a lost *Sphæria* is noticed by the bulletin of the Torrey Botanical Club. This fungus, the *S. barbirostris*, was discovered by Dufour in the department of Landes, France, over forty years ago. Since then no specimen has been found until lately, when Mr. J. B. Ellis rediscovered it on some maple-bark at Vineland, New Jersey.

AMONG some insects sent to Prof. Lockwood, of Freehold, New Jersey, as damaging the wheat, he identified that terrible microscopic hemipteran, the chinch-bug. The specimens came from Morris County. The Hessian fly is unusually troublesome this year in New Jersey.

IN a recent lecture before the Natural History Society of Harvard College, Prof. J. D. Whitney asserted that the "Calaveras skull" is undoubtedly of Pliocene age. Chemical analysis had shown it to be a true fossil, its organic matter being almost entirely lost, and the lime phosphate replaced by carbonate. Prof. Whitney had himself chiseled away from the skull the substance of the matrix in which it was imbedded when found in the strata underlying Table Mountain.

THE *Polytechnic Review* mentions the discovery, in South America, of a species of fibrous plant suitable for paper-making. The specific nature of the plant and the locality of its growth are kept secret. It is asserted that a No. 50 thread of the fibre "cannot be broken by the strength of ordinary fingers without snapping." The plant grows wild, and is, when full grown, taller than a man, in some cases even higher than a man on horseback. In the natural state it is of a brown color, but is easily bleached to pure white.

A SERIES of grammars of Indo-Germanic languages is announced as forthcoming from the press of a Leipsic publishing-house. There will be eight grammars in the series —namely, Indian, Iranic, Greek, Italic, German, Irish, Lithuanian, and Slavic. The Indian grammar will be by Prof. W. D. Whitney, of Yale College, and he has gone to Europe to see the work through the press.

DR. BROWN-SÉQUARD has been appointed the successor of Claude Bernard in the professorship of Physiology in the College of France—an eminently well-merited appointment. Dr. Brown-Séquard is a native of Mauritius, born in 1818, soon after that island had been taken from the French and made a British possession. His father, Dr. Edward Brown, was a native of Philadelphia, and his mother a native of Mauritius and of French origin. He is eminent as an investigator of brain and nerve organization.

IT has been observed by Pasteur that some bacteria are killed by a temperature of 109° Fahr. This fact he uses to explain the impossibility of inoculating birds with anthrax or carbuncle. But if the temperature of birds be lowered artificially, they would, he inferred, be inoculable, supposing the temperature to be the obstacle. This inference he confirmed by experiment; having kept a fowl for some time in water of 75° Fahr., he succeeded in inoculating it with anthrax.

WE have to record the demise of two European astronomers of note—namely, Prof. Wolfers, of Berlin, editor of the "Year-Book" of the observatory attached to the university of that place; and Rev. R. Main, F. R. S., director of the Radcliffe Observatory, England. The former died in the seventy-sixth year of his age and the latter in the seventieth.

MAGNUS NYRÉN writes to the St. Petersburg Academy of Sciences that the great earthquake on the South American coast, in May, 1877, was perceptible at Pulkowa by a tremor of the instrument with which he was observing the passage of a star. He further states that the tremor continued sufficiently long to be satisfactorily verified, and that there was no disturbance in the neighborhood by which it could have been occasioned.

IN Natal, South Africa, grass is kept in the moist state for months by being buried in pits, the process being known as "ensilage." A pit is dug in the ground in a dry situation, and filled with fresh-cut grass, which is packed closely down and then covered with a thick layer of soil, to exclude the air. Grass thus stored is apparently unchanged in its nutritive properties; cattle consume it with avidity, and thrive well upon it.

A STATUE commemorative of Giordano Bruno, the philosopher and martyr of science, will be dedicated at Rome on February 17, 1879. He was burned at the stake in that city on the same day of the year 1600, on the charge of being an "obstinate heretic."

Prof. O. C. MARSH.